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ORIGINAL ARTICLES

STUDIES IN GANGETIC ALLUVIUM OF UNITED PROVINCES

II. SOILS OF SANDILA *TAHSIL* IN HORDOI DISTRICT

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(Received for publication on 19 December 1945)

(With one text-figure)

SANDILA *tahsil* forms the south-eastern part of the district of Hardoi in the central United Provinces and lies in latitude 27°4′ north and longitude 80°30′ east, being nearly mid-way between Lucknow and Hardoi. It has a total expanse of about 558 square miles and the entire area has been sub-divided administratively into four *parganas* (small sub-divisions), *viz.* Sandila, Gondwa, Kalyanmal and Balamau.

(*a*) *Topography and soils*

In the north and north-east the *tahsil* is bounded by the river Gomti, which flows in tortuous curves and in the west is the river Sai. Between these two rivers there is an expanse of apparently level country which can be sub-divided broadly into three parts depending upon the topographical conditions.

These are : (1) the tract of uplands between the watershed of the Gomti and that of the Behta, a small rivulet which originates in the north-west of *pargana* Sandila, nearly eight miles from the Gomti and flows in the centre of the *tahsil.* The soil of this area is reputed to be sandy-loam in the north but improves slightly in texture as it approaches the Behta. There are several *jhils* (low-lying pockets) in this area which are liable to inundation during the rains.

(2) The land lying between the Behta and the Lucknow Branch of the Sarda Canal is occupied by a low-lying imperfectly drained tract having large stretches of *usar* (alkaline) lands. This is approximately six miles in breadth in the south-east but broadens to nearly eight miles in the north-west. The total length is about 16 miles.

(3) A strip of land, nearly eight miles broad and slightly narrowing down as it goes north, between the Lucknow Branch of the Sarda Canal and the river Sai is occupied again by a slightly high-lying area in which the soil is medium loam in texture [Zaidi, 1931].

(*b*) *Agriculture*

The total cultivated area of the *tahsil* is assessed at approximately 210,000 acres, out of which nearly 60 per cent is cultivated during the *rabi* and 53 per cent during the *kharif*—13 per cent being the area which is double-cropped. Irrigation is not very deficient, the percentage of wet to total cultivated area in 1931 was only 32, but this has now increased to 56 as a result of the introduction of the Sarda Canal. About 24·0 per cent of the cultivated area is reported to grow wheat alone or mixed and 21 per cent barley in the *rabi.* The chief crops of the *kharif* are the millets (*jowar* and *bajra*) ; the acreage under these is assessed at about 23 per cent of the total cultivated area. Paddy occupies only about 8 per cent and pulses, chiefly *arhar*, 7 per cent. The area under non-food crops, mainly sugarcane, is reported to be 18 per cent.

The distribution of the crops on the main soil types described in the present paper is as follows :

Type 1 soils usually grow sugarcane, wheat and barley with *jowar* as the main *kharif* crop. The better classes of land in soil type 2 grow wheat and barley in the *rabi* and *arhar* and *jowar* in the *kharif ;* but on lighter types only a mixed crop of *arhar* and *jowar* or *bajra* is possible. Type 3 soils usually grow paddy in the *kharif* and barley or gram in the *rabi.* Wheat is also cultivated on good quality loams with better drainage conditions.

(c) *Climate*

Unfortunately the complete meteorological data for Sandila proper are not available. In Table I the average rainfall data for Sandila are presented along with other data for Lucknow. Lucknow is only about 30 miles east of Sandila and the climate of the two places from the soil point of view is not expected to vary much. From Table I it can be seen that the average total rainfall for the year is only 34·79 inches and that the maximum precipitation takes place during the months of June, July, August and September when approximately 31 inches of rain are usually received. The other four inches are received during the remaining part of the year. Winter rains are scanty. The highest temperatures are attained during the months of April, May and June when the relative humidity is also low. During the hottest part of the year the absolute maximum temperature is recorded to be as high as 115°F. During these months, therefore, considerable desiccation of the soil takes place. Winters are never very severe and are usually frost free. The coldest months are those of December and January and the absolute minimum has been recorded as low as 34°F. However, during these months the relative humidity is fairly high. The climate in general can be characterized as semi-arid (Table I).

TABLE I

Rainfall data for Sandila (average of 42 years) and other meteorological data for Lucknow (average of 22 years)

Months	Rainfall (inches)	Temperature			Relative humidity (per cent)
		Maximum °F.	Minimum °F.	Mean °F.	
January	0·73	74·0	46·7	60·4	81·9
February	0·38	78·8	50·9	63·9	71·9
March	0·32	91·5	60·3	75·9	52·7
April	0·11	102·4	70·9	86·7	40·1
May	0·53	105·0	77·8	91·4	46·1
June	4·60	100·5	81·3	90·9	69·3
July	10·65	92·2	79·3	85·8	83·7
August	10·00	90·3	78·6	84·4	87·5
September	5·68	92·1	76·5	84·3	81·3
October	1·38	91·2	65·5	78·4	72·2
November	0·11	83·3	52·8	68·0	75·5
December	0·30	75·7	46·2	61·0	81·9
Average .	34·79	89·8	66·2	78·0	70·3

Lang's factor for the locality is 35 mm. per degree centigrade and Meyer's N.S. quotient 124·7. These figures clearly show that the climate of the locality would favour semi-arid type of soil formation. According to Jenny [1929], the N.S. quotient for the chestnut-brown steppe soils of the United States of America is 100-180 ; and it would appear that the climatic soil zone for the locality under survey may on these considerations be a type of chestnut-brown soil. However, it may be noted that the limit of annual temperatures in the United States of America for the chestnut-brown zone is between 8°-12°C., but the mean annual temperature of the Sandila *tahsil* would be approximately 25°C.

(d) *Methods*

The details of technique adopted for the survey of soils were the same as those reported in Part I of this series [Mukerji, Agarwal and Mukerji 1944]. A number of pits were dug at sites selected

at random; and the morphological characters as well as field reactions were recorded on the soil profiles *in situ*. Soil samples were brought to Cawnpore where detailed chemical, mechanical and physico-chemical analyses were made.

Samples of the size of 2 mm. were used for all analysis. Mechanical analysis was carried out by the international pipette method using ammonia as the dispersion agent. Hydrochloric acid extract was made according to the method prescribed by the A.E.A. [Wright 1938]. *p*H values were determined in N-KC1 using hydrogen electrode. Water extract was prepared from a 1 : 5 soil-water mixture and filtered with the help of a Chamberlain filter candle. The individual exchangeable bases were determined in the leachate prepared through the use of neutral ammonium acetate, the total of which was reckoned as the total exchangeable bases.

EXPERIMENTAL

On the basis of a large volume of data collected in the course of the survey, the soils of the Sandila *tahsil* have been classified into three distinct soil types, the distribution of which is shown on the map (fig. 1). The profile descriptions along with the analytical data for a representative soil profile under each type are given below and the results are discussed specially in reference to their pedological aspects.

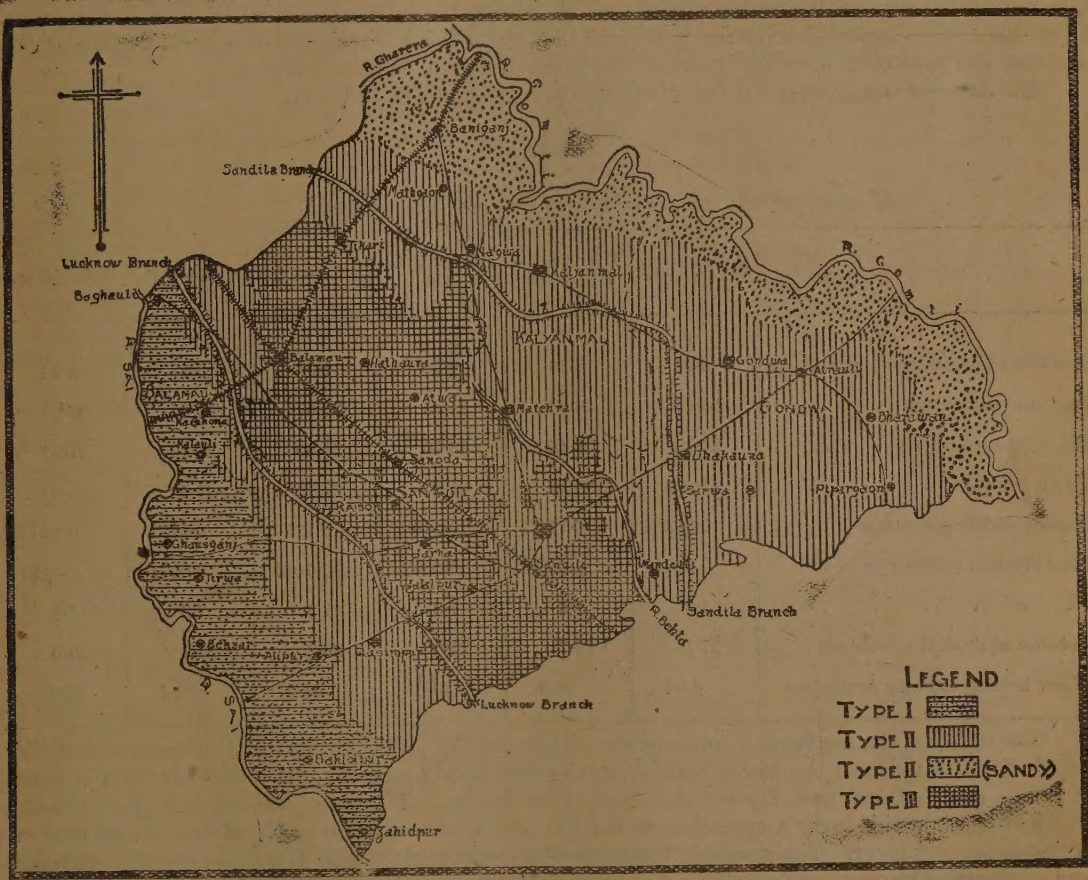

FIG. 1. Tahsil Sandila—Soil Types
(Scale 1 i --4 miles)

(i) *Type 1*

The soils belonging to this type occur towards the west of the *tahsil* bordering the Sai river. This belt of land has an average breadth of about four miles and is slightly high-lying. The high bank of Sai is well marked but is sandy and liable to inundation during high floods. The soils of the other part of the zone are good sandy loams. The profile description is given below :

Morphology

I. 0—1 ft. 2 in. Whitish grey loamy soil without any structure ; loosely packed ; non-calcareous, gritty and slightly alkaline.

II. 1 ft. 2 in.—1 ft. 10 in, 1 ft. 10 in.—3 ft., 3 ft.—4 ft. Slightly greyish yellow loamy soil with more of clay ; granular in structure ; more compact than the top layer ; calcareous and alkaline ; embedded with small fragments of *kankar* towards the bottom ; roots visible up to 3 ft.

III. 4 ft.—5 ft., 5 ft.—6 ft. Light yellowish grey tending to be ashy-grey at the bottom ; sandy in texture ; highly calcareous material rather loosely held ; embedded with big sized *kankars* about 1 in.—1½ in. in diameters ; markedly alkaline.

The profile was sampled in the village Kachhauna from a cultivated field which is being irrigated by wells. The soil is reported to be highly fertile and usually bears a good wheat crop. The topography is flat and the water table is 15 ft. during the summer and 10 ft. during monsoons. From the morphological description it is clear that the soil has developed over a calcareous parent material and that there are slight signs of eluviation of clay in the lower layers.

The data for the mechanical and other analyses are given in Table II.

TABLE II

Mechanical and other analyses of Sandila soils (Type I)

Particulars	0-1 ft. 2 in.	1 ft. 2 in.—1 ft. 10 in.	1 ft. 10 in.—3 ft.	3 ft.—4 ft.	4 ft.—5 ft.	5 ft.—6 ft.
	A		B		C	
Coarse sand percentage	0·48	0·26	0·20	1·06	0·97	3·20
Fine sand percentage	55·25	36·03	31·45	36·67	41·25	53·23
Silt percentage	26·10	31·45	30·20	29·80	28·10	21·25
Clay percentage	17·50	30·10	31·90	27·75	23·50	15·50
Organic carbon percentage	0·312	0·172	0·140	0·125	0·125	0·109
Total nitrogen percentage	0·0504	0·0490	0·0392	0·0462	0·0364	0·0210
*p*H	7·3	7·6	7·8	7·9	7·9	7·8
Moisture equivalent percentage	27·1	28·7	31·0	29·2	2·71	29·0
Water holding capacity percentage	44·7	53·3	51·1	54·6	53·2	52·4

The data for the mechanical analysis show that the top layer contains little clay, but that clay has been eluviated into the lower horizon and is distributed more or less uniformly up to a depth of 4 ft. The bottom two layers are again poor in clay. Fine sand content is high at the top which confers on this layer a typical open texture but decreases again in the B-horizon only to increase in the last layer. The greater colloidal matter content of the clay B-horizon makes it compact and moderately impervious to water. Nitrogen and organic matter are high at the top but decreate to a very low figures as we go down in the profile.

The chemical composition of the soils belonging to this type is shown in Table III.

TABLE III

Analysis of the hydrochloric acid extract of Sandila soils (Type I)

Percent ais dry basis

Particulars	0—1 ft. 2 in.	1 ft. 2 in.—1 ft. 10 in.	1 ft. 10 in.—3 ft.	3 ft.—4 ft.	4 ft.—5 ft.	5 ft.—6 ft.
	A		B		C	
Moisture	0·17	0·27	0·31	0·24	0·21	0·15
Loss on ignition	1·61	1·93	2·11	2·61	1·94	2·78
Total insolubles	86·15	80·41	73·89	72·53	74·20	70·86
Fe_2O_3	2·48	2·00	3·44	2·96	2·80	1·96
Al_2O_3	5·54	9·53	11·24	12·12	8·28	8·84
CaO	0·43	0·62	2·04	2·88	3·00	5·81
MgO	1·04	1·11	1·40	0·72	1·91	1·92
K_2O	1·22	1·21	1·46	1·56	1·16	0·88
P_2O_5	0·111	0·119	0·080	0·098	0·126	0·143
CO_2	0·00	0·23	1·05	2·67	3·48	5·44

Moisture figures show the same trend as clay but the loss on ignition figure is higher for the bottom most layer. This high ignition loss is not accounted for by the clay content. The top layer in every case was found to be more siliceous than the B-horizon. It seems that silica, being more resistant to weathering than the other components, is left behind while the other materials are leached out of the upper horizons. This fact is further corrobotated by the hydrochloric acid insolubles figures for B-horizon being in general slightly more than those for the C-horizon. Sesquioxides show accumulation in the B-horizon. The distribution of these constituents is evidently been influenced by the distribution of clay in the soil profile. Lime and magnesia increase gradually with depth. The magnesia content seems to be fairly high showing the richness of the parent material in this ingredient. The soil seems to be rich in potash too, the vertical distribution of which in A and B-horizons seems striking. The accumulation of silica in the top layers and eluviation of sesquioxides, specially alumina, in the bottom layers are signs of weak podsolization.

The results of the analysis for the water extract of the soil profile are presented in Table IV and those for the exchangeable bases in Table V.

TABLE IV

Analysis of water extract of Sandila soils (Type I)

Depth	Total solids (per cent)	Percentage of total cations			M. e. per cent.			
		Ca	Mg	Na+K	CO_3	HCO_3	Cl	SO_4
0—1 ft. 2 in.	0·0452	30·0	60·0	10·0	*nil*	0·50	0·06	Traces
1 ft. 2 in.—1 ft. 10 in.	0·0552	32·5	46·0	21·5	*nil*	0·67	0·08	Traces
1 ft. 10 in.—3 ft.	0·0488	39·9	37·5	23·6	*nil*	0·79	0·06	Traces
3 ft.—4 ft.	0·0900	33·3	42·8	23·9	*nil*	1·15	0·08	Traces
4 ft.—5 ft.	0·1104	31·8	53·2	15·0	*nil*	1·00	0·72	Traces
5 ft.—6 ft.	0·0876	41·4	41·4	17·2	*nil*	1·04	0·16	Traces

The data for the analysis of the water soluble salts of the soil profile show certain very interesting characteristics. The total solids are not high but have a tendency of accumulation with depth probably as a result of the presence of the clayey B-horizon. Of the cations, calcium and magnesium form the majority and in the top layer the monovalent ions are present only to an extent of 10 per

cent ; but in the B-horizon they increase to about 24 per cent decreasing again to 15-17 per cent in the C-horizon. The accumulation of the monovalent ions in the B-horizon coupled with its clayey nature is responsible for its indurated character. The majority of the anions consists of bicarbonates. Carbonates are absent, sulphates are present in traces and chloride content is small. Bi-carbonates show a distinct trend of being washed down in the profile. The higher bi-carbonate content of the lower layers confers on them a markedly alkaline character. The striking feature is the richness of the extract in magnesium as compared to calcium, the water extract throughout being of a predominating magnesian character.

TABLE V

Analysis of the exchangeable bases of Sandila soils (Type I)

Depth	Total exchange-able bases m.e.	As percentage of total exchangeable bases			
		Ca	Mg	K	Na
0—1 ft. 2 in.	10·33	67·76	29·91	2·33	*nil*
1 ft. 2 in.—1 ft. 10 in.	16·63	69·75	28·44	1·81	*nil*
1 ft. 10 in.—3 ft.	15·07	57·73	37·42	2·78	2·07
3 ft.—4 ft.	11·84	38·85	52·53	3·53	5·07
4 ft.—5 ft.	11·52	38·19	50·52	1·56	9·73
5 ft.—6 ft.	7·57	25·09	65·39	9·51	*nil*

The total exchange capacity is not high. The bulk of the exchangeable bases consists of divalent cations. The monovalent bases are not more than 11 per cent, being higher in lower layers, of the divalent bases, calcium forms the majority in the first three layers but the position becomes reverse in the last three layers, where magnesium comes out as the predominating cation. Sodium saturation is nil in the first two layers and increases with depth reaching a maximum value of 9·73 in the fifth layer. The richness of the water extract in magnesium was evident from Table V. It appears that the exchange complex gets more saturated with magnesium in the bottom layers than in the top layers although the magnesium content of the exchange complex in the top layers is high enough. The B-horizon is, further, rich in sodium cation and this makes the clay of that horizon slightly sticky and deflocculated in water. The potash saturation is low throughout except in the last layer.

(ii) Type 2

This soil type occurs towards the eastern part of the *tahsil* in the area between the river Gomti and the rivulet Behta. The belt of the land is approximately 16 miles in breadth in the south but converges to about eight miles when it traverses north. There is anothe⁻ strip of land on the other side of the *tahsil* on which this soil type occurs bordering the area occupied by type 1 soils. These two belts of land presumably meet somewhere further north. Near the river Gomti there is a narrow low-lying stretch of land, the soils of which are similar genetically to those under this type but are highly sandy in character. The distribution of type 2 soils, along with its sandy sub-type, is shown on the map (fig. 1).

The soil profile is of the following type :

Morphology

I. 0-1 ft., 1 ft.—1 ft. 9 in. Light grey or browinsh grey gritty soil ; loamy in texture ; loosely packed ; non-calcareous and slightly alkaline to neutral in reaction ; roots visible.

II. 1 ft. 9 in. —3 ft., 3 ft.—4 ft. 4 in. Light grey with some shade of yellow or red ; slightly compact ; clayey loam in texture ; granular in structure ; brown rust mottlings together with dark brown concretions of the size of the pea visible ; non-calcareous and neutral to slightly acidic in reaction.

III. 4 ft. 4 in.—5 ft., 5 ft.—5 ft. 1 in. Light brown to yellowish brown sandy soil ; rather loosely held ; rust streaks visible ; non-calcareous and neutral in reaction.

A number of profiles belonging to this soil type were studied. Mechanical composition along with other data of a typical profile sampled from village Atrauli are given in Table VI.

TABLE VI

Mechanical and other analyses of Sandila soils (Type 2)

Particulars.	0-1 in.	1 ft.—1 ft. 9 in.	1 ft. 9 in.—3 ft.	3 ft.—4 ft. 4 in.	4 ft. 4 in.—5 ft.	5 ft.—5 ft. 11 in.
	A		B			C
Coarse sand percentage	0·85	1·02	1·48	2·10	0·15	0·16
Fine sand percentage	51·23	52·96	43·32	42·11	49·45	53·75
Silt percentage	24·40	24·85	23·55	21·08	21·35	20·25
Clay percentage	15·35	18·27	26·45	28·08	26·60	22·10
Organic carbon percentage	0·2166	0·1615	0·1330	0·1007	0·1045	0·0869
Total nitrogen percentage	0·0700	0·0672	0·0546	0·0546	0·0462	0·0533
*p*H in KCl	7·8	7·3	7·2	7·2	7·1	7·0
Moisture equivalent percentage	26·0	22·9	26·4	28·4	27·0	28·1
Water holding capacity percentage	44·6	45·7	46·1	48·6	51·3	51·0

The results of mechanical analysis show that there are feeble signs of eluviation of clay into the lower layers and that the fine sand content is high at the top, decreasing in the B-horizon and increases again in the bottom most layer. Coarse sand content is high in the top four layers as compared with the bottom two layers. Organic matter decreases regularly with depth and so does total nitrogen. *p*H is slightly alkaline at the top and decreases gradually till it becomes more or less neutral at the bottom. The profile does not contain any calcium carbonate. The characteristic difference between type 2 and type 1 profiles described previously is the non-calcareous nature of the former which confers on this type entirely different properties.

The composition of the hydrochloric acid extract of the soils belonging to type 2 is shown in Table VII.

TABLE VII

Analysis of the hydrochloric acid extract of Sandila soils (Type 2)
(Per cent air dry basis)

Particulars	0—1 ft.	1 ft.—1 ft. 9 in.	1 ft. 9 in.—3 ft.	3 ft.—4 ft. 4 in.	4 ft. 4 in—5 ft.	5 ft.—5 ft. 11 in.
	A		B		C	
Moisture	1·01	0·92	2·52	1·22	1·59	1·13
Loss on ignition	3·22	2·12	2·14	3·38	2·60	2·95
Total insolubles	86·05	86·05	82·37	78·67	79·18	80·00
Fe_2O_3	3·20	3·60	4·24	5·48	5·40	4·92
Al_2O_3	4·00	4·24	6·66	7·62	10·86	7·76
CaO	0·42	0·49	0·38	0·43	0·38	0·28
MgO	0·91	0·93	1·16	1·29	1·20	1·30
K_2O	0·20	0·94	0·92	1·14	1·01	1·14
P_2O_5	0·09	0·09	0·09	0·08	0·07	0·13
CO_2	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*

Moisture follows the same trend as the distribution of clay and so are in general the loss on ignition figures. Hydrochloric acid insolubles are high at the top two layers and decrease in the B-horizon increasing slightly again in the last layer. This behaviour is correlated with the fine sand content of the profile. Sesquioxides follow the distribution of clay being higher in the B-horizon. Lime seems to be completely leached out of the profile but magnesia and potash show signs of accumulation

with depth. It seems that magnesia leaching started after the entire amount of lime had been washed out of the profile. From the data for type 1 soils we had evidence of the richness of the parent material in magnesia, but it appears that in the above type, although calcium has been leached out more or less completely, magnesia leaching is still in progress. Table VIII contains the results of the analysis of the water extract and Table IX those of the exchangeable bases.

TABLE VIII

Results of the analysis of the water extract of Sandila soils (Type 2)

Depth	Total solids per cent	Percentage of the total cations			M. e. per cent			
		Ca	Mg	Na+K	CO_3	HCO_3	Cl	SO_4
0 in.—1 ft.	0·080	13·6	53·2	33·2	*nil*	0·043	*nil*	Traces
1 ft.—1 ft. 9in.	0·080	7·9	63·3	28·8	*nil*	0.043	*nil*	Nil
1 ft.9 in.—3 ft.	0·072	5·1	59·8	35·1	*nil*	0·086	*nil*	Traces
3 ft.—4 ft. 4 in.	0·060	7·9	64·0	28·1	*nil*	0·033	*nil*	Nil
4 ft. 4 in.—5 ft.	0·074	2·9	73·5	22·6	*nil*	0·016	*nil*	Traces
5 ft.—5 ft. 11 in.	0·080	4·8	38·0	57·2	*nil*	0·040	*nil*	Traces

TABLE IX

Exchangeable bases in Sandila soils (Type 2)

Depth	Total exchangeable bases m.e. per cent	As per cent of total exchangeable bases			
		Ca	Mg	K	Na
0—1 ft.	8·80	76·2	11·4	4·1	8·4
1ft.—1 ft. 9 in.	9·76	73·0	19·3	3·7	4·3
1ft.-9 in.—3 ft.	11·12	72·0	25·2	1·1	1·8
3ft.—4 ft. 4 in.	11·84	62·6	23·7	2·3	11·8
4ft. 4 in.—5 ft.	9·60	68·8	20·5	0·6	9·8
5ft.—5 ft. 11 in.	9·28	64·5	30·0	0·6	4·5

The data on the analysis of the water extract show that the total water soluble solids are high at the surface. Magnesium has a tendency of accumulation with depth whereas calcium shows no such behaviour. This corroborates the finding that the profile exhibits magnesium leaching to a greater degree than calcium leaching. The last layer is unusually rich in monovalent cations. Of the anions, bi-carbonates form the majority and only traces of sulphates are present. The absence of chlorides is significant showing greater degree of leaching than what was found in type 1 profile.

From the data on exchangeable bases it is evident that the first two layers are slightly lower in total exchangeable bases but these increase in the next two layers and again fall in the last two layers. This behaviour seems to be correlated with the clay content of the soil. Exchangeable calcium is highest at the surface and shows a minimum value at the fourth layer. It increases slightly in the last two layers. Exchangeable magnesium is low in the A-horizon, becomes more in the B-horizon and is highest in the C-horizon. Divalent exchangeable bases follow in general the trend found in the water extract. The value for the exchangeable potash has been found to decrease

with depth and in the last two layers it is unusually low. The saturation with sodium falls from 8·4 per cent in the first layer to 1·8 per cent in the third layer but becomes 11·8 and 9·8 per cent in the fourth and the fifth layer, respectively. It again falls in the last layer.

(*iii*) *Type 3*

The soil type described under this head occurs as an island in the region occupied by soils of type 2 and lies on lightly lower topographical conditions. The landscape in the area occupied by soil type 3 has been disfigured at places by large stretches of *usar* (alkaline) lands. Pedologically this type is an intrazonal type being type 2 with more solentzic features. A typical description of the profile in which salinization process has not progressed to an extent to form solentzic soil is given below :

Morphology

I. 0-2 ft. Brownish grey soil with yellowish tinge ; loamy in texture ; gritty and without structure ; no concretions ; loosely packed ; non-calcareous and neutral in reaction.

II. 2 ft.-3 ft., 3 ft.-4 ft. 6 in. Brownish grey soil ; loamy in texture ; without structure ; black concretions being iron deposited round about quartz particles ; slightly more compact ; non-calcareous and neutral to alkaline in reaction.

III. 4 ft. 6 in.-5 ft. 3 in., 5 ft. 3 in.-6 ft. Lighter brown soil ; sandy loam in texture ; gritty and without structure ; no concretions ; loosely packed ; non-calcareous ; neutral to alkaline in reaction.

Although the second layer shows very slight signs of induration this does not appear to be due to clay. The clay content in this type of soil was found to be more or less constant in the first two or three layers and then had a tendency to decrease downwards. The texture of the top soil can be described to be definitely heavier than what is met with under the previous two types. The presence of iron concretions in the B-horizon signifies the nearness of the ground waters. The mechanical and other general analyses of a typical profile sampled from the village Mandai, near Sandila proper are shown in Table X.

TABLE X

Mechanical and other analyses of Sandila soils (Type 3)

Particulars	0 ft.—2 ft.	2 ft.—3 ft.	3 ft.—4 ft. 6 in.	4 ft. 6 in—5 ft. 3 in.	5 ft. 3 in—6 ft.
	A	B		C	
Coarse sand percentage	2·05	4·80	0·90	0·27	0·22
Fine sand percentage	45·50	39·83	53·48	68·61	79·35
Silt percentage	24·55	24·65	18·70	12·30	7·40
Clay percentage	26·15	27·80	24·10	16·85	9·73
Organic carbon percentage	0·253	0·184	0·164	0·101	0·085
Total nitrogen percentage	0·0798	0·0322	0·0504	0·0518	0·0630
*p*H in N-KCl	7·0	6·9	6·9	7·1	7·0
Moisture equivalent percentage	25·4	27·2	27·0	21·5	17·1
Water holding capacity percentage	45·9	43·0	48·0	46·8	44·4

An examination of the data presented above clearly shows that the coarse sand fraction is comparatively high at the top layers which suggests that the soil has been subjected to slight erosion. The fine sand content increases with depth ; whereas silt and clay fractions decrease downwards. These figures show that although the top soil is a moderately heavy textured soil, the bottom layer is still sandy. Organic carbon and total nitrogen also decrease with the depth of the profile. The *p*H in the present case is more or less constant, but in other profiles of this type, which were studied,

the pH is found to increase with depth. Moisture equivalent and to some extent the water-holding capacity follow the same trend as the distribution of clay.

The chemical composition of the soils of type 3 is shown in Table XI.

TABLE XI

Analysis of the hydrochloric acid extract of Sandila soils (Type 3)

(Per cent air dry basis)

Particulars	0 ft.—2 ft.	2 ft.—3 ft.	3 ft.—4 ft. 6 in.	4 ft. 6 in.—5 ft. 3 in.	5 ft. 3 in.—6 ft.
	A	B		C	
Moisture	1·54	1·75	1·54	1·07	0·54
Loss on ignition	2·54	2·89	2·30	2·13	2·80
Total insolubles	80·32	76·39	79·10	82·39	86·62
Fe_2O_3	4·64	4·84	5·16	4·04	3·60
Al_2O_3	8·05	11·63	7·57	7·26	6·00
CaO	0·50	0·49	0·31	0·35	0·43
MgO	1·15	1·43	0·50	0·56	0·90
K_2O	1·13	0·98	1·10	0·68	0·08
P_2O_5	0·10	0·08	0·08	0·07	0·09
CO_2	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*

Moisture figures indicate the same tendency as the distribution of colloidal matter. Insoluble matter in hydrochloric acid is higher in the bottom two layers which were also found to be lowest in clay and highest in fine sand content. Sesquioxides are lowest in the bottom two layers evidently due to the lower clay content. Lime seems to be completely leached out and the leaching of magnesia is not at all prominent as in the other two types. Potash also follows the same trend as the alkaline-earth bases. In short, it seems from a study of the distribution of clay and the bases, that vertical leaching in the soil profile has been more or less completely absent. For, with a sandy layer in the bottom, we should have expected a vertical distribution of all these constituents. This is due to the fact that the soil type described above is subject to very poor drainage during the rainy season and the water table is also comparatively higher being about 15-16 ft. on the average which comes very much nearer during the rains. The bad drainage condition is further responsible for the solentzic characters of the soil type in question.

The results of analysis of the water extract of the soils from the profile described are given in Table XII.

TABLE XII

Analysis of water extract of Sandila soils (Type 3)

Depth	Total soluble solids	Water percentage of the total cations			M.e. of anions			
		Ca	Mg	Na + K	CO_3	HCO_3	Cl	SO_4
0 in.—2 ft.	0·0876	76·0	16·0	7·6	*nil*	0·48	0·35	0·034
2 ft.—3 ft.	0·0544	75·5	17·0	7·5	*nil*	0·30	0·17	0·052
3 ft.—4 ft. 6 in.	0·0688	76·5	16·6	6·9	*nil*	0·40	0·20	0·146
4 ft. 6 in.—5 ft. 3 in.	0·0688	83·2	11·2	5·7	*nil*	0·30	0·26	0·172
5 ft. 3 in.—6 ft.	0·1092	84·7	6·3	9·0	*nil*	0·14	0·25	0·294

The percentage of monovalent cations in the water extract is small and divalent cations throughout constitute more than 90 per cent of the total cations. The percentage of magnesium is also lower and calcium forms the majority of the cations in the water extract. The bulk of the anions consists of chlorides and bicarbonates. Bicarbonates accumulate at the top and carbonates are absent. The presence of sulphates and their leaching to lower levels is quite significant which is due to poor drainage in the profile.

The above profile, although shows evidence of bad drainage, is yet not in a state of advanced salinization and the soil condition is consequently not considered to be bad enough. The region, as has already been described, however, lies on an intrazonal soil type and a large percentage of the land is gradually turning into *usar*. The results of analysis of the water extract of a typical alkaline land found in the area are given in Table XIII.

TABLE XIII

Result of water analysis of a typical usar *profile in type 3 area*

Depths	Total water soluble solids	Percentage of total cations			M.e. of anions				pH
		Ca	Mg	Na+K	CO_3	HCO_3	Cl	SO_4	
0 in.—1 ft.	0·398	8·2	7·1	84·7	0·64	2·45	0·17	0·25	8·6
1 in.—2 ft.	0·252	25·2	17·5	57·5	0·42	1·77	0·07	0·04	8·3
2 ft.—3 ft. 9 in.	0·156	34·3	25·0	40·7	0·20	1·76	0·06	0·03	8·2
3 ft. 9 in.—5 ft. 4 in.	0·149	35·0	15·0	50·0	0·32	1·61	0·08	0·02	8·2
5 ft. 4 in.—5 ft. 10 in.	0·096	34·7	21·0	44·0	0·02	1·00	0·11	*nil*	8·2

A consideration of the above data clearly shows the high alkaline character of the soil. The total water solubles are very high and so is the *p*H of the soil solution specially at the surface. Monovalent cations in the water extract are on the average much above 50 per cent of the total water-soluble cations. Although bicarbonates form the majority of the anions, the presence of carbonates in sufficient quantities in the extract is significant. One of the most characteristic feature is the accumulation of total water soluble solids, sodium and potassium, carbonates, bicarbonates and sulphates in the surface layers, whereas the greatest amounts of alkaline earth bases are found in the bottom layers of the profile.

Table XIV contains the results of the analysis of the exchangeable bases in the type 3 profile.

TABLE XIV

Analysis of exchangeable bases of Sandila soils (Type 3)

Depths	Total exchangeable bases m.e. per cent	As percentage of total exchangeable bases			
		Ca	Mg	K	Na
0 in.—2 ft.	12·64	65·27	25·16	4·75	4·82
2 ft.—3 ft.	14·50	67·24	30·14	2·63	*nil*
3 ft.—4 ft. 6 in.	13·41	62·59	34·62	1·12	1·67
4 ft. 6 in.—5 ft. 3 in.	10·31	64·66	33·33	2·01	*nil*
5 ft. 3 in.—6 ft.	8·73	53·38	38·03	6·87	1·72

Total exchangeable bases in the first and second horizon have more or less the same value but the third horizon is slightly poorer in bases. The distribution of bases follows the distribution of clay in the profile. Of the bases, calcium forms the majority and this cation together with magnesium amounts to more than 90 per cent of the total exchangeable bases. The relative proportion of magnesium to calcium in the exchange complex is also low and nowhere in the profile the percentage of saturation with magnesium becomes more than that with calcium. The magnesium content, however, increases with depth and, unlike the results obtained for the water extract in Table XIII, the content of calcium decreases. Sodium saturation is maximum at the surface layer and becomes almost negligible in the other succeeding layers. The behaviour of the exchange complex in respect of sodium is significant in view of the fact that this type of soil is reputed to possess poor drainage conditions. It appears that the surface two feet of the profile is being subjected to a slow but perceptible process of sodiumization as a result of sodium rich drainage waters which remain standing on it for a considerable period during the monsoons.

Discussion

The meteorological data of the locality, the soils of which were surveyed in the present investigation, point clearly to the conclusion that the climate would favour desert and semi-desert type of soil-formation. Rainfall deficiency and high summer temperatures are two of the most characteristic features of the locality. But the four months of the rainy season are particularly wet and this wet period follows an intense desiccation during the summer. These processes lead to a typical soil formation which differes fundamentally in many respects from the well known zonal types of the desert, semi-desert and arid parts of other countries.

As in other alluvial soils of the province, the first thing to be noticed about these soils is a very scanty horizon differentiation, but a textural profile can invariably be met with. A zone of lime accumulation is also found in one of the types described. Unlike other soils of the arid regions, the mechanical composition of the profile is not the same throughout. The top layer in most cases is sandy and this is followed by a slightly heavier horizon of accumulation. Clay has been found to have eluviated to lower layers resulting in slight induration and cementation of the horizon of illuviation. The bottommost layers again come out to be sandy. These facts show that the rainfall of the locality although scanty can nevertheless permit slight eluviation of colloidal matter into the lower layers leaving on the surface a highly silicious skeleton. Similar observations were made for the morphology of Unao soils described in Part I of this series [1946]. Nikiforoff [1937], in the course of the study of the morphology of soils in the Mojave desert in the United States as well noted one of the principal zonal characteristics of southern desert soils to be the presence of a reddish-brown clay layer in the lower part of the solum, but suggested, in view of the scanty rainfall, that this clay layer might be formed *in situ* by hydrolytic decomposition and not through a process of eluviation. In the central United Provinces, however, the amount of rainfall received is much more than what is recorded for Mojave desert and it seems doubtful if the above suggestion of Nikiforoff would hold good for this region.

A closer examination of the chemical composition of the soils reveals that chemical weathering of the soil complex is not well pronounced, since the distribution of silica and sesquioxides follow in most cases the distribution of clay in the soil profile. The topmost layer is more silicious in character and the content of this ingredient falls again in the B-horizon. Of the sesquioxides, iron seems to be more mobile than alumina and this fact suggests that the clay is more allitic, iron being present mostly in an uncombined form in the silicate complex. However, a detailed analysis of the separated clay portion which is proposed to be taken up in these laboratories at a later date, would throw more light on these factors. Lime has been washed down in all the three cases, but in the case of type 1 there has been an accumulation of lime in lower layers in the form of big calcium carbonate nodules. The behaviour of magnesia is interesting, since in all the three cases studied, its leaching has been found to be highly pronounced. The quantities of acid-soluble lime in all layers of the three types, except the last three layers of type 1 soil, have been found to be small in comparison with acid-soluble magnesia. Sigmond [1938] pointed out that in calcareous soils lime is leached

out on a larger scale than magnesia and that magnesia accumulates at the cost of lime. Joffe [1936] further states that in the case of brown soils solodization process favours the release of magnesium. It seems that in the soils described in the present paper, there has been a greater leaching of calcium as compared with magnesium due to the calcareous nature of the parent material and that with the start of the process of solodization magnesium leaching has further become prominent. The data on analysis of the water extract of the three soil types lend further support to these conclusions.

The results of analysis of the water extract clearly show that the soil solution is richer in magnesium than in calcium. This suggests, as has already been pointed out, that calcium leaching had been in progress in the past and now the process of the release of magnesium is much in evidence. According to Joffe [1936], this is an indication of the start of the process of solodization in the case of soils of the semi-arid regions. The total content of the monovalent bases in the water extract is fairly high and on this account one would expect high sodium saturation in the exchange complex as well. However, the sodium saturation in the exchange complex has not been found to be high, being on the average below 12 per cent of the total exchangeable bases. It is in this important respect that these soils differ materially from the soils of the adjoining district of Unao [1946]. Moreover, the exchange complex shows unusual richness in magnesium cation and the degree of saturation with this base increases with the depth of the profile. The degree of saturation with sodium cation also, in general, increases with the depth of the profile except in the case of soils belonging to type 3. It can be construed from these data that the process of solodization goes hand in hand with the process of the increase in the magnesium content of the exchange complex. It may be significant to note that these two bases, viz. magnesium and sodium, are not considered to be very desirable for the fertility of the land. In this connection it may be mentioned that Hissink [1938] noted magnesian character of the exchange complex of Dutch saline soils. He further showed that as the weathering in those soils increased exchangeable calcium was gradually replaced by exchangeable magnesium.

Summary

Soil survey of *tahsil* Sandila in the Hardoi district of the central United Provinces was conducted on modern pedological principles.

Three soils types (called type 1, type 2 and type 3) have been recognized and their morphological, chemical and other data have been presented and discussed. A regional map showing the distribution of these soil types has been prepared.

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THE EFFECT OF MANURING AND CROPPING ON THE VERTICAL DISTRIBUTION OF CARBONATES IN PUSA CALCAREOUS SOILS

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(With three text-figures)

THE soil in the Indo-Gangetic alluvium around Pusa is highly calcareous containing 40 to 50 per cent of chalk and is a rare type occurring in India. Because of its rare occurrence both here as well as in other countries, little work seems to have been done with regard to the distribution of carbonates in different layers of such a soil. The only work of importance is that of McMiller [1926], who reports the concentration of carbonates in two Minnesota soil types. At depths varying from 12 to 27 in. below the surface, he found zones of pronounced carbonate accumulation, in which lime concretions were thickly distributed and the carbonate content ranged from 25·3 to 45·5 per cent. In the unaltered material below it varied from 7·7 to 22·7 per cent. The role of chalk in the Indo-Gangetic calcareous soil at Pusa was studied by the author [Das, 1931], but no data are available with regard to its distribution in different layers of the soil and the effect of manuring and cropping on it. The present investigation was undertaken to obtain information on this aspect.

Experimental

A series of nine permanent manurial plots, 20 ft. by 25 ft. each, was laid out in 1920 in the Pot Culture House Area of the Chemical Section at the old site of the Imperial Agricultural Research Institute at Pusa. Manures were applied to the plots once every year just before the monsoon. In these plots *ragi* (*Eleusine coracana*) was raised as the *kharif* (summer) crop followed by either wheat or oats as the *rabi* (winter) crop. Before the date of collecting soil borings in October, 1933, *ragi* was raised in these plots for 14 seasons, and wheat and oats for 2 and 11 seasons respectively. Nitrogen, phosphate and potash were applied singly or in combination as ammonium sulphate, superphosphate, and potassium sulphate respectively. In one of the plots mustard cake was applied. Three inches soil borings up to a depth of five feet were taken in October, 1933, from the above nine plots and also a fallow plot lying adjacent to them. Five representative spots were selected in each plot and 3-in. borings taken from each of them were composited for the purpose of analysis in this investigation.

In these soil samples calcium carbonate was determined by a simple method developed by the author [Das, 1944]. For easy reference it may be stated here.

The method consists in boiling for five minutes or agitating at intervals for half an hour at room temperature a known weight of soil with a measured quantity of half-normal hydrochloric acid solution, in slight excess of 4 to 5 c.c. and 50 c.c. of water, in a 500 c.c. conical flask and then titrating back the excess acid with decinormal caustic soda solution using phenolphthalein as indicator. The end point is very sharp and the titre figures are quite reproducible. One c.c. of N/2 HCl corresponds to 0·025 gm. of $CaCO_3$. The excess acid used in the process is diluted in the presence of 50 c.c. of water to about N/25 strength which is too dilute to have any appreciable secondary reactions with the soil complex, organic matter or soil bases. The close agreement obtained between the results of this process and those given by the standard gravimetric method in a large number of typical Indian soils reported in the paper cited lends support to the above contention. Therefore, the method has proved to be of sufficient accuracy to warrant its employment in routine soil analysis when a large number of samples have to be quickly tested.

For the sake of comparison all the carbonates in the soil are expressed in terms of $CaCO_3$ in Table 1, although some of them may be attributed to $MgCO_3$.

TABLE I

The distribution of $CaCO_3$ at different depths of the fallow and the permanent manurial plots in Pusa calcareous soil

3-inch soil section	Depth in inches	Fallow plot	Plot 1 manure		Plot 2 Mustard cake		Plot 3 N+P+K		Plot 4 N+P		Plot 5 N+K		Plot 6 N+K		Plot 7 N		Plot 8 P		Plot 9 K	
		$CaCO_3$	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.	$CaCO_3$	Conc.
1 . . .	0—3	37·60	35·00		35·18		35·00		35·65		35·85		36·00		36·23		36·15		35·65	
2 . . .	3—6	37·08	35·43		35·40		35·48		35·68		36·35		36·43	Low	36·93	Low	36·43	Low	35·93	
3 . . .	6—9	36·93	35·50		35·23		36·00		36·00		37·03	Low	37·08		37·68		36·68		36·75	Low
4 . . .	9—12	36·43	35·40	Low	35·50		35·68		35·85	Low	36·43		37·23		38·23		37·15		36·50	
5 . . .	12—15	36·85	35·65		35·08	Low	36·85	Low	36·93		37·08		39·33		40·00		37·73	Medium	36·00	
6 . . .	15—18	36·88	35·15		35·75		37·50		36·73		37·85	Medium	38·00	Medium	40·23	Medium	39·35		38·43	Medium
7 . . .	18—21	37·68	35·08		36·00		37·25		35·90		41·00		38·65		40·85		43·50		40·93	
8 . . .	21—24	37·35	35·58		35·75		36·73		37·50	Medium	44·33		41·65		43·00		46·25		42·98	
9 . . .	24—27	38·00	36·55	Medium	35·75		37·25		39·50		45·98		45·00		46·00		46·85	Max.	44·35	Max.
10 . . .	27—30	38·48	38·00		37·58		38·00		44·55	Max.	47·50	Max	44·85	Max.	47·08	Max.	46·60		46·18	
11 . . .	30—33	38·75	42·85		39·40	Medium	39·35	Medium	45·23		46·60		47·00		46·25		47·25		44·75	
12 . . .	33—36	40·00	42·65		39·18		40·75		37·25		42·65		42·65		46·58		44·10		35·65	
13 . . .	36—39	38·75	43·50	Max.	40·50	Max.	41·23	Max.	31·50	Min.	30·48		33·68		38·93		32·25		30·93	Min.
14 . . .	39—42	39·75	42·75		42·50		42·50		30·65		30·43	Min.	31·93	Min.	30·50	Min.	33·50	Min.	30·50	
15 . . .	42—45	40·25	41·50		39·75		43·50		35·00		35·35		38·00		36·73		33·23		33·23	
16 . . .	45—48	40·58	38·85	Min.	35·90	Min.	37·25	Min.	40·15		43·98		46·43		46·85		45·18		45·23	
17 . . .	48—51	41·23	43·93		42·25		42·25		46·55		46·75		46·43		47·58		47·50		46·75	
18 . . .	51—54	41·33	45·85	Max.	45·23	Max.	45·58	Maxim.	44·50	Max.	45·25	Max.	45·00	Max.	44·93	Max.	44·58	Max.	44·25	Max.
19 . . .	54—57	42·50	42·93		43·18		42·23		43·50		44·75		46·75		46·35		45·50		45·23	
20 . . .	57—60	43·68	42·79		42·98		41·25		44·90		46·00		45·23		45·50		45·23		44·93	
Average $CaCO_3$ per 3-inch soil section		39·00	39·25		38·40		39·08		38·68		40·58		40·87		41·82		41·25		39·76	
																		Mean	39·87	

In order to form an approximate idea of the distribution of $CaCO_3$ at different depths, the per cent average $CaCO_3$ per foot is stated in Table II. The average yields of *ragi*, wheat and oats raised in the plots before the soil boring was taken are given in Table III.

TABLE II

The per cent average $CaCO_3$ per foot of the fallow plot and the permanent manurial plots in Pusa calcareous soil

Per cent average $CaCO_3$ per foot	Plot No.	1	2	3	4	5	6	7	8	9
	Fallow plot	No manure	Mustard Cake	N+P+K	N+P	N+K	P+K	N	P	K
1st foot	37·01	35·33	35·33	35·54	36·80	36·42	36·69	37·27	36·60	36·21
2nd "	37·17	35·37	35·65	37·08	36·77	40·07	39·41	41·02	41·71	39·59
3rd "	38·81	40·01	37·98	38·84	41·63	45·68	44·88	46·48	46·20	42·73
4th "	39·83	41·65	39·66	41·12	34·33	35·06	37·51	38·25	36·04	34·97
5th "	42·19	43·88	43·41	42·83	44·86	45·69	46·85	46·09	45·70	45·29

TABLE III

Average grain yields in lb. of ragi (Eleusine coracana), *wheat and oats of the permanent manurial plots in Pusa calcareous soil*

Kind of grain	Plot No. 1	1	2	3	4	5	6	7	8	9
	Years averaged	No Manure	Mustard cake	N+P+K	N+P	N+K	P+K	N	P	K
Ragi .	14 : 1920 to 1933 .	3·94	16·47	16·61	15·92	14·39	8·07	11·51	6·18	3·93
Wheat .	2 : 1922-23 to 1923-24	4·38	6·06	6·38	6·09	7·68	7·63	5·91	5·56	4·88
Oats .	11 : 1920-21 to 1923-33, except above two years.	7·95	14·37	13·22	11·96	10·42	11·02	8·10	8·93	6·95

From Table II it is seen that in the six plots numbering 4 to 9 there are two zones of maximum carbonate concentration at third and fifth foot with an intermediate zone of minimum carbonate concentration at the fourth foot. Such distribution of carbonate is apparently absent in the remaining four plots. In them a gradually increasing concentration of carbonate seems to occur from the surface downward. Here the intermediate layer of minimum carbonate concentration is masked while taking the average carbonate content per foot. On a closer examination, however, of the individual data of carbonate concentration at different depths in Table I, similar zones are found to be the characteristics of all the cropped plots. The fallow plot, on the other hand, forms an exception where a gradual rise in carbonate concentration occurs from the surface downward with of course very insignificant fluctuations in the 2nd to 6th, and 13th and 14th layers which are within experimental errors. This plot was never cultivated nor manured and so represents the undisturbed soil.

In Table I the zones of carbonate concentration are classified into four broad divisions in all the permanent manurial plots, such as : (1) low, (2) medium, (3) maximum, and (4) minimum. There are two zones of maximum carbonate concentration with one of minimum concentration lying between them in every cropped and manured plot including the no-manure plot. Above them there are two zones of low and medium carbonate concentrations. The first three plots numbering

1 to 3 have their zones of minimum carbonate concentration at the 16th layer from 45 to 48 inches. These three plots may thus be placed in one group for comparison. Of these, however, the two manured plots, 2 and 3, behave similarly and have all zones of $CaCO_3$ concentration absolutely identical, whereas the no-manure plot 1 has the upper three zones located slightly differently, although the lower two zones are identical with those of the other two plots. Hence the no-manure plot has been included in this group with this reservation.

In the remaining six plots numbering 4 to 9 the area of minimum $CaCO_3$ concentration extends from 9 to 12 inches. Of these, the plots numbering 4 and 9 have an area of 12 inches each from 12th to 15th layers, and the rest 9 inches each from 13th to 15th layers. These plots thus differ from the previous group of three plots numbering 1 to 3 in having wider areas of minimum carbonate concentration with considerable shifting of three upper zones except the lowest maximum $CaCO_3$ zone which extends from the 16th to 20th layer in all the six plots. These may, therefore, be placed in a separate group.

That this classification of the nine cropped plots into two groups, namely, (I) the plots numbering 1 to 3, and (II) those numbering 4 to 9, is justified by the experimental evidence detailed in Table I, will be obvious on further scrutinizing the similarity of minimum and maximum $CaCO_3$ values of the soil horizons in the two groups of plots as set forth in Table IV.

TABLE IV

Similarity of minimum and maximum $CaCO_3$ values of the two groups of plots

Group	Plot No.	Per cent $CaCO_3$ in 3 in. soil layers	
		Minimum	Maximum
	Fallow	36·43	43·68
I	1	35·00	45·85
	2	35·18	45·23
	3	35·00	45·58
	Average	35·06	45·55
II	4	30·65	46·55
	5	30·43	47·50
	6	31·93	47·00
	7	30·50	47·58
	8	32·25	47·50
	9	30·50	46·75
	Average	31·04	47·15

From Table IV it is seen that the two groups of plots numbering 1 to 3 and 4 to 9 are quite distinct in behaviour with respect to their individual minimum and maximum $CaCO_3$ values. As for example, these values vary between 35·1 and 45·6 in group I and 31 and 47·2 in group II on the average, whereas they vary between 36·4 and 43·7 in the fallow plot which shows no similarity with either of the above two groups of the treated plots.

In the same way, the zonal distribution of $CaCO_3$ shown in Table I clearly indicates the distinct behaviour of these two groups of plots, both of which stand on a footing quite different from the fallow plot. In the latter, the $CaCO_3$ content gradually rises from the surface downwards with very insignificant variations here and there which are quite unlike its pronounced fluctuations in all the other plots.

This phenomenon singles out the fallow plot from all the rest where the unequal vertical distribution of $CaCO_3$ resulting from the differential action of manuring and cropping over a number of years is quite remarkable. On the other hand, this gradually rising $CaCO_3$ concentration with

depth in the fallow plot has virtually remained almost intact, being not at all affected by the action of fertilizers, cropping and other cultural operations as in the case of the treated plots. This condition, therefore, represents the original profile characteristic of this fallow plot as well as of the entire adjacent area where the nine other plots were initially laid out for permanent manurial experiments in 1920. Since then 27 crops (Table III) were raised for 14 years in these plots after manuring every year before different depth samples were collected from them in 1933 for the present investigation. Although the original profile characteristic as well as the mechanical composition of all these plots including the fallow plot in their several soil horizons might be considered to remain more or less the same in 1920, the year of initiating the manurial experiments, subsequent changes were gradually brought about during the following years in the soil texture of the different horizons of the treated plots by the unequal movement of $CaCO_3$ due to the differential action of manuring, cropping and other cultural operations. As a result, the proportion of $CaCO_3$ in the soil horizons varied from 35 to 48 per cent in them as against 37 to 44 per cent in the fallow plot and exhibited quite irregular rise and fall in its concentration in different horizons as shown in Table I. It is, therefore, primarily the proportion of $CaCO_3$ which preponderates over other soil particles and materially affects the fluctuations of soil texture in different soil horizons, as will be shown in the sequel (Table VI), irrespective of the fact that the proportion of the ultimate soil particles, or for the matter of that, the mechanical composition of different soil horizons may remain more or less the same, when calculated on the soil residues left after the elimination or destruction of $CaCO_3$. Moreover, the proportion of ultimate soil particles is not liable to such irregular fluctuations as that of the fleeting substance like $CaCO_3$ due to the action of manuring and cropping, and will therefore remain almost at the same level in the control (fallow) and the treated plots. The fluctuation of $CaCO_3$ status and not the proportion of ultimate soil particles is thus primarily responsible for varying the texture of different soil horizons.

Considering further the data in Table I, it is found that the upper zone of maximum carbonate concentration occurs from 30 to 45 inches downward in the no-manure plot 1 and 36 to 45 inches in the manured plots numbering 2 and 3, whereas the same is found from about 18 to 24 inches downward in the rest of the treated plots. This shows the accumulation and concentration of carbonate nearer the surface in plots 4 to 9 than in the first three plots. In the latter group I the no-manure plot 1 has the upper zone of maximum $CaCO_3$ concentration starting from six inches higher layers than the manured plots 2 and 3; but in the next two lower zones all the three plots behave similarly. Therefore, the leaching of carbonate from the upper layers has taken place deeper in the plots 1 to 3 than the plots 4 to 9. This is brought about by rain-water dissolving CO_2 evolved from the respiration of plant roots. The CO_2 in the presence of water reacts on $CaCO_3$ and forms soluble calcium bicarbonate which leaches down into the deeper soil layers unlike the insoluble $CaCO_3$. The bicarbonate, however, eventually decomposes into CO_2 and $CaCO_3$. The latter is deposited increasing its concentration in the lower layers.

The solvent action of different fertilizer salts applied singly or in combination and also of mustard cake on $CaCO_3$ of the soil must be different. Further, the effect of these fertilizers on crop production in the differently manured plots is also different as detailed in Table III. This difference in crop production will obviously reflect on the proportions of CO_2 evolved from the respiration of plant roots and its consequent solvent action on $CaCO_3$. It is, however, difficult to differentiate between the rates at which the $CaCO_3$ is rendered soluble in the different plots by the solvent action of fertilizer salts and that of CO_2 produced by the respiration of plant roots under the soil conditions, where the reacting substances are static and where the volume and the rate of movement of water are comparatively small. Therefore, the solubility of $CaCO_3$ is not identical at different depths of the various plots from the operation of both these factors as evidenced by their varying $CaCO_3$ concentration. Thus the classifications of the treated plots into two groups is conditioned by the unequal $CaCO_3$ concentration due to the cummulative effect of these two factors and other cultural operations rather than the grounds of different crop yields alone which are not liable to easy differentiation. Fig. 1 demonstrates the varying $CaCO_3$ concentrations of these two groups of treated plots. In the no-manure plot 1, of course, cropping and other cultural operations except manuring have

effected the distribution of $CaCO_3$ in different layers. On the other hand, the fallow plot shows an increasing $CaCO_3$ concentration with depth. This gives a true picture of the carbonate status of the soil *in situ* which has not been disturbed by any external agencies, such as cultivation, manuring or cropping. Here the solubility of $CaCO_3$ is the least and therefore the variation in $CaCO_3$ concentration at different depths is at a minimum. The extent of the solubility effect in the various plots is graphically shown in Fig. 1.

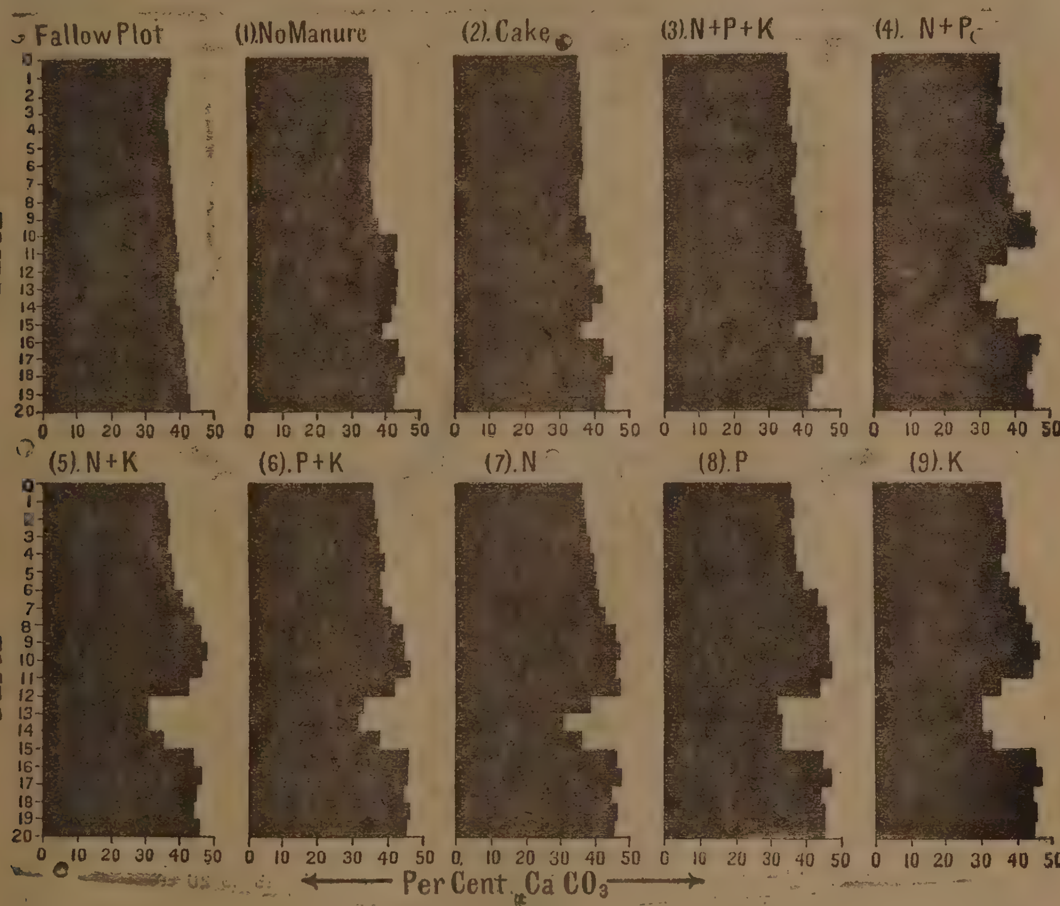

FIG. 1. The concentration of $CaCO_3$ at different depths of the fallow and the permanent manurial plots in Pusa calcarious soils

Taking the average of all the depths, it is seen in the last row of Table I that the mean percentages of $CaCO_3$ per depth of three inches are fairly constant in the different plots. Slight variations noticed are not significant at all and are obviously due to the accumulated experimental errors involved in 20 estimations in each case and also to the variation in the specific gravities of different soil horizons, for which no allowance has been made. It may, therefore, be concluded that the total $CaCO_3$ content of the soil up to a depth of five feet remains practically steady. It does not appreciably leach beyond five feet, but distributes itself in a characteristic way from layer to layer within this depth due to its differential solubility according as several fertilizer salts are applied singly or in combination and produce thereby varying crop yields in different plots.

Regarding the concentration of $CaCO_3$ at different depths of the various plots, it is noticed that there are two maxima and one minimum in every manured and cropped plot including also the no-manure plot with cropping, but none in the fallow plot which shows a continuously rising gradation of $CaCO_3$ indicating the absence of factors operating in the other plots. Plots numbering 1 to 3 and 4 to 9 form two distinct groups in their having characteristic zones of carbonate concentration with definite positions of their own. This is clearly demonstrated in Fig. 2. The data of plots (1) and (3), as well as (6) and (9) produce two distinct groups of graphs with characteristic maxima and minima. As the graphs from the rest of the plots fall into either of these groups, they are not reproduced in that figure to avoid overcrowding.

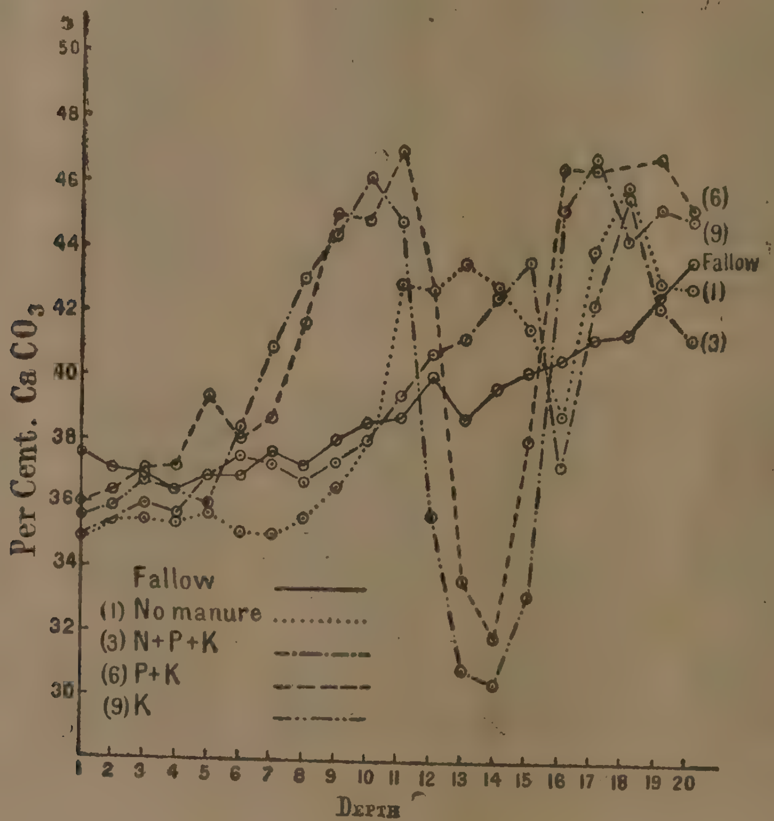

Fig. 2. The concentration of $CaCO_3$ at different depths of the two proups of the permanent manurial plots in Pusa calcareous soil

When these two groups of graphs are compared with the curve of the fallow plot, the pronounced effect of manuring and cropping on the movement of $CaCO_3$ in calcareous soils is made evident. Of course, the no-manure plot 1 shows only the effect of cropping on the vertical distribution of $CaCO_3$.

No lime or chalk concretions were encountered in any layer of the plots, while taking the soil borings. Chalk concretions are however formed as a perennial product in the bed of the river Gandak which flows by and surrounds the Pusa Estate almost on three sides. A sample of such concretions collected from the river bed gave the composition shown in Table V.

TABLE V

The chemical composition of chalk concretions collected from the bed of the river Gandak at Pusa

Constituents	Per cent
Loss on ignition	0·69
Silica and insoluble matter	37·21
Ferric oxide	3·11
Alumina	3·13
†Lime	29·56
Magnesia	1·80
Potash	0·28
Soda	0·33
Sulphate, SO_3	*Nil*
Phosphate, P_2O_5	0·07
* Carbon dioxide	23·22
	99·40
Undetermined	0·60
TOTAL	100·00
* Equivalent $CaCO_3$	52·83
† Calculated $CaCO_3$	52·78

It is seen from Table V that practically the whole of the carbonate present occurs in the form of $CaCO_3$ and constitutes about 53 per cent of the chalk concretions. The maximum amount of $CaCO_3$ encountered in the present inquiry was about 48 per cent in the Pusa calcareous soil within a depth of five feet which is only 5 per cent lower than the $CaCO_3$ content of chalk concretions. Its concentration may be higher in the still deeper soil layers.

The colour of the different layers of soil is grey and does not exhibit any marked difference with varying carbonate concentration.

The mechanical composition or rather the proportion of ultimate soil particles in the different soil horizons being not liable to much fluctuation due to manuring and cropping as the fleeting substance like $CaCO_3$, the changes in the soil texture will primarily depend upon the proportion of $CaCO_3$. So an attempt was made to discover if any relationship existed between the carbonate content of different soil layers and the soil texture as typified by moisture equivalent determined by the method of Briggs and McLane [1910]. The moisture equivalent is ordinarily taken to be the means of an indirect measurement of soil texture or mechanical analysis.

Out of ten plots which were examined for carbonate content, only two plots numbering 4 and 9, which were manured with N+P and K respectively, were chosen for the determination of moisture equivalent. The results are set forth in Table VI.

TABLE VI

The relationship between the moisture equivalent of different soil layers of Pusa calcareous soils and their varying calcium carbonate contents

3-inch soil sections	Depth in inches	Plot No. 4— N+P		Plot No. 9. K	
		$CaCO_3$ per cent	Moisture equivalent per cent	$CaCO_3$ per cent	Moisture equivalent per cent
1	0—3	35·65	14·25	35·65	15·08
2	3—6	35·68	15·00	35·93	16·17
3	6—9	36·00	14·73	36·75	18·33
4	9—12	35·85	15·93	36·50	19·42
5	12—15	36·93	16·33	36·00	18·58
6	15—18	36·73	16·28	38·43	8 00

TABLE VI—*contd.*

The relationship between the moisture equivalent of different soil layers of Pusa calcareous soils and their varying calcium carbonate contents

3-inch soil sections	Depth in inches	Plot No. 4. N+P		Plot No. 9. K	
		$CaCO_3$ per cent	Moisture equivalent per cent	$CaCO_3$ per cent	Moisture equivalent per cent
7	18—21	35·90	14·25	40·93	18·17
8	21—24	37·50	15·87	42·98	18·58
9	24—27	39·50	20·57	44·35	22·00
10	27—30	44·55	22·67	46·18	23·00
11	30—33	45·23	22·00	44·75	21·50
12	33—36	37·25	15·92	35·65	13·83
13	36—39	31·50	11·92	30·93	9·33
14	39—42	30·65	12·50	30·50	10·92
15	42—45	35·00	14·08	33·23	12·67
16	45—48	40·15	18·67	45·23	25·33
17	48—51	46·55	23·08	46·75	24·76
18	51—54	44·50	20·33	44·25	22·50
19	54—57	43·50	19·00	45·23	22·92
20	57—60	44·90	20·25	44·93	23·75

It is seen that there is a fairly direct proportionality between the carbonate content and the moisture equivalent of different soil layers. No such relationship was however observed by McMiller

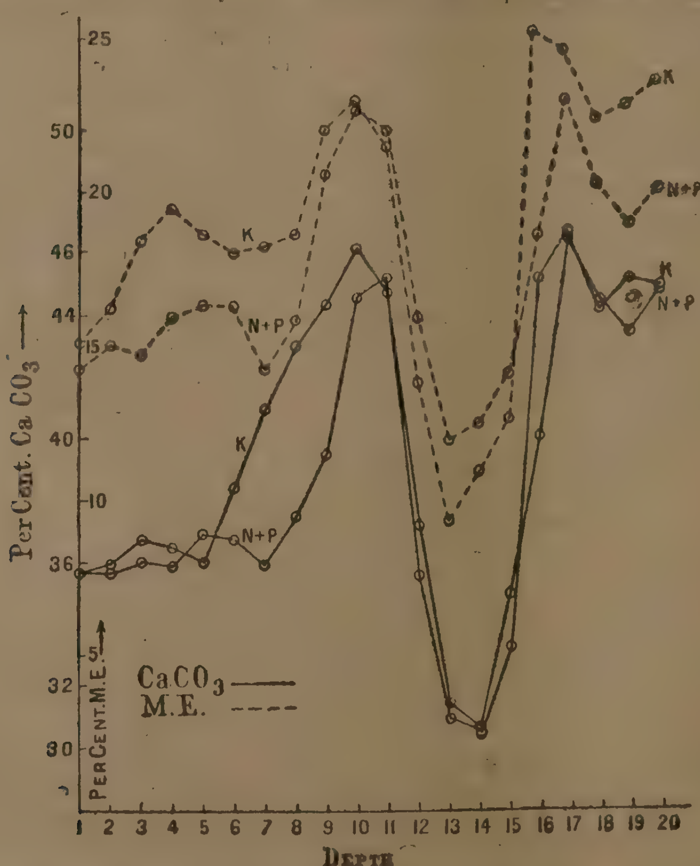

FIG. 3. The relation between $CaCO_3$ and moisture equivalent of different layers of Pusa calcareous soils

[1926] while examining two Minnesota calcareous soil types. The relation in the present instance can be better noticed in Fig. 3, where the percentages of $CaCO_3$ and moisture equivalent of different soil layers are plotted against the corresponding depths.

It is seen that the curves of $CaCO_3$ and moisture equivalent for calcareous soils of the two plots run almost parallel, showing a fairly direct relationship between the two. That is to say, the proportion of $CaCO_3$ regulates the texture of different soil horizons as typified by their moisture equivalent. Lower moisture equivalent will generally mean coarser texture and better permeability. Therefore, under natural soil processes greater leaching out of $CaCO_3$ and consequent lower contents of lime in these layers would be expected. This is what has actually taken place in plots 4 and 9 in 33 to 48 inches and 33 to 45 inches layers respectively which have the lowest range of $CaCO_3$ and moisture equivalents. The fact that the increasing amount of $CaCO_3$ in a calcareous soil beyond a certain limit acts as an inert substance like sand and helps in the mechanical opening of the soil, thereby improving its physical texture with the concomitant decrease of its moisture-holding capacity was demonstrated by the author long ago [Das, 1931].

Incidentally, the effect of manuring and cropping on the soil reaction was studied. Five permanent manurial plots and the adjoining fallow plot were included in this study. The results are given in the Table VII.

TABLE VII

The effect of manuring and cropping on the reaction (pH) of Pusa calcareous soils

3-inch soil sections	Depth in inches	Fallow plot	Plot 1 No-manure	Plot 2 Mustard Cake	Plot 7 N	Plot 8 P	Plot 9 K
		*p*H	*p*H	*p*H	*p*H	*p*H	*p*H
1 . . .	0—3	7·83	7·80	7·84	7·83	7·74	7·90
2 . . .	3—6	7·85	7·87	7·86	7·76	7·78	7·90
3 . . .	6—9	7·91	7·90	7·91	7·91	7·77	7·95
4 . . .	9—12	8·00	7·92	7·91	7·89	7·92	8·00
5 . . .	12—15	8·00	7·97	7·94	7·93	7·95	8·00
6 . . .	15—18	8·01	7·95	7·94	7·84	7·87	7·99
7 . . .	18—21	7·98	8·00	7·95	7·90	7·97	7·96
8 . . .	21—24	7·94	7·97	8·00	7·90	7·91	7·99
9 . . .	24—27	7·84	7·95	7·96	7·86	7·90	7·98
10 . . .	27—30	7·95	7·95	7·96	7·83	7·91	7·99
11 . . .	30—33	7·95	7·93	7·99	7·86	7·90	7·89
12 . . .	33—36	7·92	7·87	7·97	7·91	7·91	7·95
13 . . .	36—39	7·85	7·87	7·94	7·84	7·91	7·84
14 . . .	39—42	7·82	7·92	7·93	7·78	7·90	7·80
15 . . .	42—45	7·86	7·93	7·93	7·83	7·74	7·83
16 . . .	45—48	7·93	7·92	7·93	7·76	7·72	7·93
17 . . .	48—51	7·90	7·99	7·92	7·87	7·86	7·95
18 . . .	51—54	7·85	7·98	7·94	7·90	7·84	7·92
19 . . .	54—57	7·89	7·95	7·95	7·86	7·86	7·95
20 . . .	57—60	7·92	7·91	8·00	7·89	7·97	7·96

From Table VII it is evident that there is no appreciable difference in *p*H at the various depths of the differently-treated plots. It shows that the high proportion of $CaCO_3$ preponderates over all other soil constituents and rules the reaction of calcareous soils. It does not permit any variation of the reaction in spite of continuous manuring and cropping every year.

SUMMARY

Three inches soil borings up to a depth of five feet were taken of nine permanent manurial plots and an adjacent fallow plot in Pusa calcareous soils. The concentration of $CaCO_3$ of these different soil layers was determined by a simple method developed by the author [Das, 1944].

It has been found that there are two zones of maximum carbonate concentration with one of minimum concentration lying between them in every manured and cropped plot, including also the no-manure plot. Above them there are two more zones of low and medium carbonate concentrations.

The fallow plot forms an exception where a gradual rise in carbonate concentraction occurs from the surface downward. This plot was never cultivated nor manured.

The differential effect of fertilizer salts as well as cropping on the movement of $CaCO_3$ in the differently-manured plots has been discussed.

The total content of $CaCO_3$ of these calcareous soils up to a depth of five feet remains practically constant. It does not leach beyond five feet, but distributes itself in a characteristic way from layer to layer within this depth due to its solubility according as different fertilizer salts are applied singly or in combination and produce varying crop yields in different plots.

The colour of the different soil layers is grey and does not show any marked difference with varying carbonate concentration.

There is a fairly direct proportionality between the carbonate content and the soil texture as typified by moisture equivalent.

The reaction (pH) of calcareous soils is unaffected by manuring and cropping owing to their dominant $CaCO_3$ content.

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THE BIOLOGICAL DECOMPOSITION OF GREEN MANURES

III. THE CHEMICAL CHARACTER OF HUMUS IN COMPOST HEAPS

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The chemistry of humus has been the subject of attack for the last 150 years. The nature of the organic residues and the conditions under which they decompose chiefly influence the chemical nature of humus.

Several attempts were made since 1880 to synthesize humus but without success. These attempts have been reviewed by Waksman [1926]. Deherain [1888] was the first to indicate that humus may be a mixture of lignin and protein. This idea coupled with other observations, viz. (i) interaction of tannin-phenolic bodies like lignin with protein leading to the formation of 'humic bodies' [Moeller, 1916], and (ii) the average chemical composition of organic matter of soils [Waksman, 1929 and Waksman and Stevens, 1930], 78 per cent of which accounted for the two constituents like lignin and protein, led to the successful solution of this important problem, almost simultaneously but independently by Hobson and Page [1932] and Waksman and Iyer [1933]. Although these workers have established the constituents of synthetic humus they have not been able to show the proportion in which the two important constituents are linked together in natural or synthetic humus. The work described here reveals the proportion in which the lignin and the protein are present in humus by working directly with composts.

Degree of humification by hydrogen peroxide, though a crude measure, is still a useful guide to the amount of humification both in composts and soils in the absence of any quick and suitable method. Carbon and nitrogen ratios of the raw material and finished composts are no doubt most reliable but this determination is expensive and takes time and hence is not quite suitable for routine application. So far no comparative study of the two methods appears to have been made chiefly in respect of organic matter in composts.

If hydrogen peroxide removes all the humified organic matter and if humus is a ligno-protein complex as suggested by the above workers then almost all the lignin of the humic fraction should be removed during oxidation with peroxide. That a certain fraction of protein in the soil organic matter resists the action of peroxide beyond a certain strength is known from the work of McLean [1931]. Whether such a thing occurs in a compost is yet to be studied. It was therefore decided to conduct lignin and nitrogen determinations of the peroxide-treated compost in addition to the carbon and nitrogen ratios as on the untreated ones. These observations will give a comparison between the C : N ratios of the ligno-protein complex and the degree of humification. A study of the C : N ratio of the fresh material and compost and also of the oxidized material and the degree of humification may give an approximate estimate of loss of organic matter in a compost heap during fermentation for which there is no satisfactory method available at the moment. The C : N ratio and the lignin content of the residue after peroxide extraction will throw some light on the nature of the resistant material. If the lignin content be appreciable with a wide C : N ratio the residual material may resist further decomposition unless some available nitrogen and carbohydrates may be added for the requirements of the microflora.

Experimental methods

All the composts analysed in this paper were manufactured on the various Ceylon tea estates. They were dried at 100°C. powdered and sieved through a 64-mesh sieve for all the following analytical determinations :

(1) *Lignin*. This was determined on the hydrolysed product with 5 per cent H_2SO_4 for one hour as recommended by Norman and Jenkins [1934]. The hydrolysed product was then treated overnight with cold 72 per cent sulphuric acid. Volume was then made up to 800 c.c. with water and this was boiled for two hours.

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(2) *Extraction with peroxide.* The method employed was described by Shrikhande [1933]. The strength of peroxide used was 3 per cent.

(3) *Extraction with water.* Two grams of the material were extracted with the same volume of water and for the same length of time as with peroxide.

(4) *Total nitrogen.* Was determined by the usual Kjeldahl method.

(5) *Organic carbon.* Was estimated by the Robinson, McLean and Rice William method [1929].

(6) *Water and peroxide soluble constituents.* These were determined by evaporating to dryness the extracts on a water bath.

Results and discussion

1. *Carbon and nitrogen ratios of composts*

These ratios are presented in Table IA. All the composts examined have on an average a standard ratio of 12 :1 with the exception of the Gona Adika. The variation in the C and N values of different composts is apparently due to the difference in the nature of fermentable materials used on different estates.

Table I

Carbon : nitrogen ratios of composts, of their residues on peroxide treatment and of the peroxide soluble fraction

(Results expressed on 100 gm. of original compost)

Compost	C : N ratios of composts A			C : N ratios of residues B			C : N ratios of soluble fractions C		
	C	N	C/N	C	N	C/N	C	N	C/N
Galha	20·00	1·46	13·7	10·80	1·08	9·8	9·20	0·38	24·2
Ensalwatte	10·84	0·93	11·6	4·22	0·36	11·6	6·62	0·57	11·7
Beaumont	9·66	0·63	15·3	4·48	0·32	13·9	5·18	0·31	16·8
Rye	18·12	1·07	16·9	13·70	0·47	28·7	4·42	0·60	7·4
Gona Adika	32·68	4·42	7·4	15·82	1·90	8·3	16·86	2·52	6·7
Lethenty	14·70	1·09	13·5	3·80	0·26	14·6	10·90	0·83	13·1
Lethenty (dry compost)	26·64	1·75	14·9	6·58	0·46	14·3	19·56	1·29	15·1
East Holy	12·47	0·98	12·7	2·11	0·23	9·1	30·36	0·75	13·9
Tanagakelle	12·50	1·04	12·0	2·48	0·33	7·7	10·02	0·71	14·0
Wikiliya S24·2	19·69	1·75	11·2	8·74	0·52	17·3	10·64	1·23	8·7
„ S39·7	20·94	1·26	15·8	11·26	0·26	43·3	9·68	1·00	9·7
„ S39·9	25·24	1·62	15·5	12·21	0·43	28·2	13·03	1·19	11·0
„ S39·23	17·67	1·16	15·2	4·22	0·24	17·9	13·45	0·93	14·5
„ S40·1	12·92	1·12	11·5	4·84	0·22	21·8	8·08	0·90	9·0
Poonagalla A	13·81	0·94	14·7	..	..	..	..	..	..
„ B	16·93	1·35	12·5	..	..	..	..	..	..
Mahagastote 9	20·34	1·58	12·8	..	..	..	..	..	..
„ 11	23·91	1·50	15·9	..	..	..	..	..	..
„ 12	31·79	1·91	16·6	..	..	..	..	..	..

2. *Carbon : nitrogen ratios of residues on peroxide treatment of composts*

These ratios in Table IB are in general of the same order as the original composts with exceptions in Rye, Wikiliya S 39·7, Wikiliya S 39·9 and Wikiliya S 40·1. The uniformities in such ratios is due to the proportionate extraction of carbon and nitrogen by 3 per cent hydrogen peroxide. This means

in effect that the strength of peroxide employed was just sufficient to attack both carbon and nitrogen in a proportion without affecting the extra carbonaceous material. The work of McLean [1931] on soil organic matter has demonstrated that the strength of peroxide over 1·5 per cent removed a considerable amount of carbon leaving nitrogen almost unaffected, suggesting that carbon from cellulose or other carbonaceous material and not from the humus fraction was being attacked by higher concentration of peroxide than 1·5 per cent. This observation is significant in so far as it indicates a definite relationship between carbon and nitrogen of the soil humus. Such an analogy can very well be applied to composts, the only difference being that the strength of peroxide required for composts is double of that for soil humus. This should be expected because the concentration of humus in a compost is always greater than in a soil. Whether higher concentration of peroxide has an effect on carbon other than humus carbon is a matter of further enquiry. Provided the method is standardized with respect to the strength of peroxide and the period of heating, it can still serve as a useful guide to determine the degree of humification in composts.

The exceptions in Rye, Wikiliya S 39·7 and Wikiliya S 39·9 can be accounted for by the lower extraction of carbon but with Wikiliya S 40·1 although carbon was extracted slightly more than in any other compost, the nitrogen was extracted in still larger amounts. Such composts giving peroxide residues of a wider C/N may resist further decomposition and may not nitrify on account of their low nitrogen content.

3. *Carbon : nitrogen ratios of oxidized and dissolved portion of composts during peroxide treatment*

These ratios are based on the carbon and nitrogen found by difference between the two constituents in composts and residues left after peroxide treatment from Table IA and IB. The results are included in Table IC. The trend of ratios is the same on the whole like the original composts with the exception of Galha, Rye and Gona Adika. Gona Adika with the narrowest ratio continues to be an exception from the very beginning on account of the nitrogenous nature of the material used for composting.

On comparing the values for nitrogen attacked by peroxide with those in original composts in Table IA it is clear that nearly 60 per cent of the total nitrogen in composts has been rendered soluble. This value may be taken as the upper limit for the availability of nitrogen in composts as discussed in a previous communication [Shrikhande, 1945]. As the process by which such nitrogen has been extracted occurs in two stages, viz. (*i*) by mere solution as in water, and (ii) by oxidation with peroxide, it is reasonable to conclude that the nitrogen obtained purely by solvent action of this reagent should become easily available to the plant whereas nitrogen which is affected by the oxidizing action of peroxide should be rendered gradually available by the oxidation process in soil though not so readily as the former.

4. *Water soluble nitrogen and water and peroxide soluble constituents of composts*

The greater extractibility of and the different nature of peroxide extraction is clearly demonstrated by comparing the water soluble nitrogen in Table II with peroxide removable nitrogen in Table IC. The amount of nitrogen over and above that extracted by water is obviously due to the oxidizing action of peroxide besides its purely solvent action. These differences are indeed quite large and clearly indicate a specific action of peroxide on the nitrogen complex of a compost.

The availability of nitrogen should vary according to the amount and nature of nitrogen present in the original vegetable refuse. All the composts examined should easily nitrify when applied to the land if we take into consideration only the C : N ratios. What amount of nitrogen will actually become readily available from each compost is difficult to say unless each compost is subjected to nitrification tests. But viewing the results on the basis of water solubility and easily available nitrogen, it is possible to suggest that about 10 per cent of the nitrogen which is water soluble in these composts may quickly nitrify and thus become easily available to the plant. This value is one-third of what is given by composts obtained purely from green manures underlaboratory conditions [Shrikhande, 1945].

TABLE II

Water soluble total nitrogen and water and peroxide soluble constituents of composts

(Results expressed on 100 gm. of original compost)

Compost	Water soluble N	Water soluble fraction	Peroxide soluble fraction
Galha	0·12	7·68	16·78
Ensalawatte	0·07	2·85	13·78
Beaumont	0·06	2·65	8·28
Rye	0·09	4·93	18·93
Gona Adika	0·28	9·83	49·63
Lethenty	0·14	2·83	22·14
Wikiliya S24·2	0·09	5·93	28·65
" S39·7	0·10	4·18	24·70
" S39·9	0·10	8·58	31·15
" S39·23	0·12	6·05	23·58
" S40·1	0·11	4·00	26·40
" S40·2	0·25	6·78	29·00
Poonagalla A	0·06	2·68	..
" B	0·07	3·75	..
Mahagastote 9	1·24	11·32	23·43
" 11	0·20	6·75	29·04

5. *Organic matter content of original and peroxide treated composts and the degree of humification*

Organic matter in compost depends upon the type of material and the mineral matter introduced during composting. At times lot of mineral matter in the form of soil is introduced either with the stubble or at the time of turning the heap which contributes essentially to a low organic matter content of compost and consequently there is a poor recovery of humified matter. This can clearly be noted in Beaumont compost where the initial organic matter and the humified material is the lowest of all the composts reported in Table III. The other extreme is the extremely high original organic matter content with an excellent degree of humification of 78 per cent in the Gona Adika compost. This may be the maximum limit of humification expected in compost manufactured on a large scale.

Taking into account the heterogenous nature of material utilized on various estates it is interesting to note that the organic matter content of most of the composts tested approximated to an average of 45 per cent and the degree of humification to about 60 per cent. By comparing the degree of humification with C : N ratios of composts in Table IA, it can be seen that the highest humified compost on Gona Adika has the narrowest C : N ratio whereas the lowest humified compost on Rye estate has the widest ratio. A relation therefore seems to exist between the degree of humification and the C : N ratios. The average ratio of 12 : 1 may be taken as equivalent to about 60 units of humification. A compost manufactured from a material of an average composition which is fermented for a period of three months usually suffers a loss of 30 to 40 per cent in dry matter. Such a loss brings down the ratio in the proximity of 12 : 1. Knowing therefore the degree of humification it may be possible to roughly predict the loss inorganic matter a compost had undergone during decomposition. From the above observation one unit loss of dry matter may be taken as equivalent to about two units of humification. It is rather difficult to put down any definite formula for assessing the loss of dry matter in compost heaps because of the absence of data for both the original amounts of material taken and the finished compost obtained therefrom.

TABLE III

Organic matter content of original composts, their residues on peroxide treatment and the degree of humification

(Results expressed on 100 gm. of original compost)

Compost	Organic matter in composts	Organic matter in residues	Organic matter humified	Degree of humification
Galha	37·60	11·68	25·92	68·9
Ensalwatte	22·00	14·43	7·57	34·4
Beaumont	15·24	14·07	1·17	7·7
Rye	42·29	35·26	7·03	16·6
Gona Adika	79·44	17·36	62·08	78·2
Lethenty	51·20	39·92	11·28	22·0
Lethenty (dry compost)	48·60	21·23	27·37	56·4
East Holi	27·03	11·21	15·82	58·48
Tanagakelle	41·79	14·00	27·79	66·5
Wikiliya S24·2	47·56	20·62	26·94	56·6
,, S39·7	47·24	26·36	20·88	44·3
,, S39·9	53·85	28·00	25·85	48·0
,, S39·23	38·34	13·22	25·12	65·4
,, S40·1	43·50	16·39	27·11	62·3
,, S40·2	44·06	15·62	18·44	41·9
Mahagastote 9	41·65	23·23	18·42	44·2

6. *Lignin content of original composts and of their residues after peroxide treatment*

Table IV includes percentage loss of lignin on peroxide extraction of composts in addition to the lignin of original composts and their respective residues. Looking at the last column of Table IV it is interesting to note that 60 per cent of lignin in composts has been removed by peroxide treatment with the exception of Tanagakelle. Since hydrogen peroxide does not appreciably affect the lignin content of any plant material, it appears therefore reasonable to presume that the lignin in the original plant materials has been transformed into such a form as to be liable to attack by peroxide. The transformation which is the most likely one is its conversion to humus in association with the protein synthesized by the micro-organisms during the process of decomposition. An indication of such an association is obtained by definite proportionality between the extraction of carbon and nitrogen by the peroxide as shown in Table 1A and 1B. This is suggestive of the lignin-protein nature of compost humus.

A certain proportion of lignin has resisted the attack of peroxide. This fraction may either be still present in its native state, i.e. it was unaffected during fermentation and thus could not combine with the micro-organic protein to form humus, or that the strength of peroxide was not sufficient enough to attack this fraction of lignin. The former seems to be the chief possibility in so far as it is known that the process of composting although rapid in the first few days slows down considerably after about 50 per cent of dry matter has been lost. This view has been confirmed by the recovery of cellulose and other structural constituents from fermented vegetable materials. The strength of hydrogen peroxide has been shown to be just sufficient for the attack of humified material in compost as pointed out in section 2.

TABLE IV

Lignin content of original compost and their residues on peroxide extraction
(Results expressed on 100 gm. of original compost)

Compost	On original compost	On residue	Percentage of loss of lignin peroxide treatment
Galha	19·50	11·24	42·36
Ensalwatte	11·04	4·57	58·61
Gona Adika	35·99	2·27	93·67
Lethenty	16·11	4·94	69·31
Lethenty (dry compost)	26·68	10·01	62·47
East Holi	11·37	3·21	71·78
Tanagakelle	11·87	11·47	3·37
Wikiliya S24·2	19·73	9·21	53·01
,, S39·7	20·44	3·99	80·48
,, S39·9	27·32	12·87	52·89
,, S39·23	16·40	5·35	67·40
,, S40·1	17·60	5·23	70·28
,, S40·2	21·28	5·68	73·31
Mahagastote 11	21·11	5·09	75·88
,, 13	39·50	20·65	47·55

7. *Lignin-nitrogen relationship in the peroxide removable fractions and also in the residues after peroxide treatment of composts*

Having obtained indications of the lignin-protein nature of humus by working directly with natural humic bodies in composts it was thought desirable to work out the proportions, if possible, of the two important constituents of the humus nucleus from the data in hand. Although it would have been more convenient to obtain such relationship in terms of lignin and protein as done by Hobson and Page [1932] and Wakesman and Iyer [1933], it was thought desirable to restrict consideration to lignin-nitrogen relationship for two reasons, viz. (1) the protein conversion factor of 6·25 is purely arbitrary, and (2) the nitrogen present in the vegetable material from which these composts were manufactured was not entirely of a protein character. All the composts manufactured on tea estate usually contain an appreciable amount of refuse in the form of tea leaf prunnings and refuse tea. These materials contain about 25-30 per cent of their total nitrogen in a non-protein form as caffein. Table V presents such lignin-nitrogen relationship in the humic and non-humic portions of composts.

TABLE V

Lignin-nitrogen relationship in the humic and non-humic fraction

Compost	Peroxide soluble fraction			Residue after peroxide extraction		
	Lignin	Nitrogen	Lignin/Nitrogen	Lignin	Nitrogen	Lignin/Nitrogen
Galha	8·26	0·39	21·5	11·24	1·08	10·5
Ensalwatte	6·47	0·57	11·4	4·57	0·36	12·6
Gona Adika	33·72	2·52	13·4	2·27	1·90	11·9
Lethenty	11·17	0·83	13·5	4·94	0·26	18·9
Lethenty (dry compost)	16·67	1·29	12·9	10·01	0·46	21·7
East Holi	8·16	0·75	10·9	3·21	0·23	13·8
Tanagakelle	0·40	0·71	5·5	11·47	0·33	49·4
Wikiliya S24·2	10·46	1·23	8·5	9·27	0·52	17·8
,, S39·7	16·45	1·00	16·4	3·99	0·26	15·3
,, S39·9	14·45	1·19	12·2	12·87	0·43	29·7
,, S39·23	11·05	0·93	12·0	5·35	0·24	22·8
,, S40·1	12·37	0·90	13·8	5·23	0·22	23·4
			Mean 12·58			*Mean* 20·65

Relative variance 0·0911 (P=0·05) *Relative variance* 0·2412 (P=0·05)

It will be noted from the ratios of lignin to nitrogen in the humified fraction that they are fairly constant, whereas there is a greater variation between such ratios in the case of residues after peroxide treatment or the non-humic fractions. On a statistical examination in terms of relative variances it is found that the difference between them is significant. It can thus be concluded that the humus nucleus consists of 12 parts of lignin to 1 part of nitrogen whereas the non-humic fraction has the ratio of the order of 20 : 1 for lignin to nitrogen. This non-humic fraction may resist further decomposition on account of its proportionately high lignin content. This may also resist nitrification in the soil. This clearly explains why decomposition considerably slows down after a certain amount of organic matter has been lost; an equilibrium is thus established between the humic and non-humic portions of composts.

Hydrogen peroxide has therefore proved a valuable reagent by which it became possible not only to throw light on the lignin-protein nature of humus but also to establish a quantitative relationship between the two important constituents of the humic nucleus. Another importance of these findings lies in the fact that these conclusions have been arrived at by working directly with natural humic substances such as composts rather than with artificial preparations obtained by the interaction of chemical reagents.

Summary

1. All the composts examined contain a suitable carbon-nitrogen ratio approximating to the standard of 12 : 1.

2. C : N ratio of the residues left after peroxide treatment are very close to those of original composts with a few exceptions. The C and N are thus extracted in a definite proportion by 3 per cent hydrogen peroxide without attacking the unhumified portion of composts. A relationship between the degree of humification and the C : N ratio of composts has been indicated. Provided the method of peroxide treatment is well standardized with respect to its strength and the time of extraction, it can still serve as a useful guide in determining the degree of rot in decomposed vegetable materials.

3. Hydrogen peroxide has been shown to extract more than water. Water extracted about 10 per cent of total nitrogen whereas peroxide removed about 60 per cent of nitrogen in composts. The limits of availability of nitrogen in composts have been discussed on the easily soluble and quick availability hypothesis. The range as shown by these experiments also lies between 20 per cent and 60 per cent obtained by the nitrification and crop recovery tests of other workers.

4. By the help of peroxide the organic matter of composts has been separated into fractions, viz. (1) humic, and (2) non-humic. The nature of humic fraction is the same as the soil humus. The C : Nratio of peroxide residues and the peroxide removable fraction coupled with the lignin estimations confirm the lignin-protein nature of humus nucleus. A quantitative relationship has also been established between the two important constituents. The lignin nitrogen ratio of the humic fraction is more or less a constant and approximates to 12 : 1 whereas there is a greater variation in the case of non-humic fraction and is of the order of 20 : 1.

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THE BIOLOGICAL DECOMPOSITION OF GREEN MANURES

IV. LOSS OF LIGNIN DURING AEROBIC FERMENTATION

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In view of several factors being involved in the decomposition and also in the determination of lignin in original and fermented materials different workers have reported different results even on similar materials. Tenney and Waksman [1929] in their studies on corn stalks, rye straw and oak leaves recorded definite losses of lignin but much less in proportion than of any other constituent. On the other hand, extensive decomposition of lignin under aerobic conditions was obtained by Philips, Wiehe and Smith [1930]. Their experiments were comparatively brief in duration and losses of lignin recorded were in some cases higher than those of cellulose. Several such conflicting views and data have been reported in the literature on the subject of decomposition of lignin. For a good review of the subject readers may refer to Norman [1936]. The subject being still controversial, a good deal of work is yet necessary to solve its intriguing nature by applying new methods which have recently been developed by Norman and Jenkins [1934] for the quantitative determination of lignin. In this paper are recorded some data on the subject of lignin decomposition in various materials including nearly half a dozen tannin materials.

Methods and results

The various plant materials were fermented aerobically in bottles as described in Parts I and II of this series [1945, 1946]. The dried material was ground to pass through 64-mesh sieve before applying the Norman and Jenkin's method [1934] for lignin determination in non-tans and Shrikhande's method [1940/a] for lignin determination in tannin materials.

Table I contains results for both the type of materials rotted aerobically for periods upto six months. The losses of lignin obtained are somewhat similar to those recorded by Norman [1935] for oat straw fermented for a period upto 12 months. In non-tan materials the maximum loss of lignin sustained by sun-flower after six months was 26 per cent and the least loss of nearly 2 per cent by gravilleas. These losses of lignin appear to be in proportion to the losses of dry matter since sun-flower had suffered a loss of nearly 60 per cent in dry matter against hardly 15 per cent by gravilleas. On an average the non-tans investigated lost nearly one-fifth of their original lignin after six months' fermentation. Addition of mineral nitrogen did not affect the loss of lignin to any appreciable extent. This loss of lignin compares very poorly with losses of cellulose and hemicelluloses, which may amount to even 60 per cent in such a period of decomposition. It is apparent therefore that lignin is not so readily available to the micro-organism as cellulose and hemicelluloses. The tannin materials on the other hand show a very small loss of lignin in similar periods although losses of dry matter were normal. This exceptional behaviour of this class of materials may again be attributed to the antiseptic properties of tannins which might inhibit the growth of micro-flora responsible for the loss of lignin as in non-tanniferous species. This exceptional behaviour of tannin materials has been reported by the author on previous occasions [1940 a, 1940 b and 1946].

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TABLE I

Aerobic decomposition of lignin in various materials at 25°C. (Results expressed on the basis of original weight)

Material	Original lignin content per cent	Percentage of loss of lignin after— 5 weeks' decomposition: Without mineral nitrogen	With $(NH_4)_2SO_4$	With $NaNO_3$	24 weeks' decomposition: Without mineral nitrogen	With $(NH_4)_2SO_4$	With $NaNO_3$
Sun flower	25·83	9·38	10·96	11·31	22·39	24·38	26·00
Dadaps	29·24	7·05	7·35	7·31	21·33	22·54	23·23
Tephrosia	28·86	5·75	6·79	9·89	17·58	19·51	20·32
Glivicidia	22·34	9·93	12·05	10·07	15·31	16·07	17·18
Maana grass	18·45	5·69	8·95	13·27	18·11	18·54	18·71
Weeds	16·82	10·00	10·76	10·19	15·96	17·18	17·86
Grairlleas	33·15	0·42	1·21	1·96	0·76	1·21	1·96
Fern	28·56	12·05	13·21	15·81	17·18	19·82	21·23
Cane reed	17·32	..	7·62	9·59	6·47	14·09	17·22
Paddy straw	15·23	..	8·41	12·08	7·62	16·29	20·51
Refuse tea	26·61	2·29	3·42	3·38	5·68	6·43	6·98
Tea leaf (Prunings)	23·93	3·47	4·63	4·93	8·02	8·36	9·12
Caesalpinia bonducella	23·85	3·06	..	..	4·61	..	..
C. sappan	17·70	4·58	..	..	9·59	..	..
C. coriaria	15·50	3·87	..	..	8·91	..	..
Terminalia belerica	23·70	2·53	..	..	7·00	..	..
Pterocarpus indicus	16·94	2·60	..	..	6·19	..	..

SUMMARY

Lignin determinations by Norman and Jenkin's method [1934] and Shrikhande's method [1940] for non-tanniferous and tanniferous species respectively indicate that lignin under aerobic conditions is by far the most resistant major constituent and suffers a small loss in a period of five weeks. This loss increases with longer periods amounting to nearly 20-25 per cent in six months. This is, however, only about one-third of the loss undergone by cellulose and hemicelluloses under similar conditions. In tannin materials losses of lignin are almost negligible and this may be attributed to the antiseptic properties of tannins which modify the micro-flora.

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CITRUS PROPAGATION STUDIES*

THE INFLUENCE OF DIFFERENT METHODS OF BUDDING, AFTER-TREATMENTS AND ROOTSTOCK VIGOUR ON BUD-BREAK, BUD-TAKE, HISTOLOGY OF BUD-UNION AND SIZE OF BUDLINGS IN CASE OF SWEET ORANGE, MANDARIN AND SOUR LIME

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(with Plates I and II)

MOST economic plants, including fruit trees, are propagated by vegetative means such as, grafting, budding, layerage and cuttage. The citrus trees, however, are propagated universally by budding and the method used is termed shield-budding or T-budding. It consists in inserting the bud of one tree, with a shield-shaped piece of bark, beneath the bark of another through a T or inverted T-shaped incision.

The scion-bud, as removed from the bud-stick, carries a thin slice of wood on its under surface but, before it is inserted beneath the bark of the root-stock, the slice of wood requires to be discarded according to some workers whereas others recommend its retension. The experience of most workers in India, England, Continent of Europe, New York (U. S. A.) and Palestine—[Sham Singh, 1938 ; Lorette, 1925 ; Feilden, 1936 ; Davis, 1922 ; Hall & Crane, 1933 ; Cheal, 1892 ; Kains, 1930 ; and Mendel, 1936] points to the view that the piece of wood, beneath the scion-bud, plays no part in facilitating its union with the stock but that, on the contrary, it may actually retard this process. Mendel [1936] says ' the older wood and pith are incapable of regeneration '. Thus, if the central core of wood in the ' shield ' is not removed, the shield has to be cut away thin to allow callus to form on the entire cut surface. It follows that from a practical standpoint, the budding of citrus should be done ' without wood '. This is in accordance with the opinion of authors referred to above who recommend complete removal of wood from the bud before inserting it into the stock, but care has to be taken that, in doing so, the bud-germ is not damaged.

Most American writers [Auchter & Knapp, 1929 ; Budd, 1914 ; Bailey, 1903 ; 1920 ; Coit, 1915 ; Fuller, 1905 ; Green, 1911 ; Hume, 1909 ; Thomas, 1920 ; Wickson, 1926 ; Hansen, 1936 ; and Maynard, 1905], on the other hand, assert that the scion-bud should have a thin piece of wood attached to it when inserted into the root-stock. One English author [Baltet, 1910], and one Indian [Naik, 1939] also agree with the American view-point. Baltet [1910] says, ' there is no harm in leaving a small particle of wood under the bark of the bud-shield ; it will help to render the union of the parts more intimate '. According to Bailey [1903-20] too ' the bit of wood probably serves a useful purpose in retaining moisture, but at the same time it interposes a foreign body between the two healing surfaces, for the bark of the bud units directly with the cambium of the stock'. In a recent study, carried out in India, Naik [1939] with meagre data concluded thus 'the superiority of inserting the bud with wood over the common Indian method of inserting the bud after removal of wood may be said to have been clearly established '. Under South African conditions, Powell [1930] does not appear to attach much importance to either method of budding as according to him ' it is largely a matter of individual experience '. Sham Singh [1938] corroborated, in general, the view held by Powell as, according to him, the difference in the two practices is conventional as with certain scions both methods gave equally good results in the Punjab. He has, however, suggested the adoption of the American method in case of grapefruit, sweet lime and sour lime, etc. where the Indian method does not work well due to the thorny nature of buds, although Cheema [1929] advises the production and selection of thornless shoots for propagating the sour lime. It is clear, therefore, that the horticultural investigators in different countries tested the suitability of the two methods of budding not only from the viewpoint of higher percentage of take of buds but also from the nature of union taking place between the scion and the rootstock.

* The present paper is a part of the thesis approved for the Degree of Master of Science in Agriculture in the University of the Punjab

The difference in the two practices lies not only in the removal and preparation of the scion-bud and the nature of the union taking place, but also in the way in which the stock seedling is treated after the bud is inserted. The technique followed in giving the 'after-treatment' or the way of treating the seedling top after inserting the bud varies considerably from country to country and even in different parts of the same country to suit either the individual preference or the conditions prevailing. Some believe in severing the stock top immediately after inserting the scion bud, others allow the stock top to remain intact till after the scion bud has united and still others prefer to give a half way cut to the stock top after inserting the scion bud. It is, however, commonly believed that these operations or 'after-treatments' play a considerable part both in the efficiency of bud-take and the proper development of bud sprouts.

It is obvious, therefore, that in testing the suitability of a particular method of budding, the after-treatment to be given should also be determined simultaneously for different kinds of fruits and different seasons of budding. With these aims in view, and also to study the nature and development of union between scion and stock and the influence of rootstock vigour on the size of budlings, citrus propagation trials were initiated in the nurseries of the Punjab Agricultural College, Lyallpur, early in the autumn of 1939 and continued till the middle of 1941.

Material used

Plots containing seedlings of rough lemon (*Citrus limonia* Osbeck), known locally as *jatti khatti* were selected in the nurseries of the Punjab Agricultural College, Lyallpur. The seedlings were growing in a uniform piece of land, which was loamy in nature and which received uniform cultural treatments ever since the seedlings were planted therein. Furthermore, the seedlings were of the same age and origin and were nearly two years old at the time of selection in autumn 1939. Notwithstanding all this, the seedlings differed considerably from one another with regard to height and thickness. Therefore, for the purpose of the trials reported here, seedlings of uniform vigour with considerably low coefficient of variability were selected as outlined in Table I.

Table I

The material used for various experimental trials

Serial No. 1	Season 2	No. of seedlings under experiment 3	Purpose of experiment 4
1	Spring 1940	504	Propagation trials with mandarin (*C. nobilis* var *deliciosa* Swingle)
2	Do.	504	Propagation trials with sweet orange (*C. sinensis* Osbeck)
3	Do.	84	The anatomy and histology of union between scion and rootstock
4	Summer 1940	558	Propagation trials with sour lime (*C. aurantifolia* Swingle)
5	Do.	240	Repetition of the propagation trials with mandarin
6	Do.	288	Repetition of the propagation trials with sweet orange
	Total	2,178	

Methods employed

Selection of seedlings and the methods of propagation studied

It is evident from Table I that 2,178 seedlings were finally selected for various trials reported here. To achieve this, about double this number was measured in the field for diameter (correct to the nearest millimeter) at nine inches above the ground level. It was thus possible to select seedlings of the required thickness and the rest, which were either too thick or too thin, were not budded.

After this, the selected seedlings were divided into different groups, based on diameter measurements and labelled accordingly. The propagation methods studied were the following:

(*a*) The Indian method of budding, in which case the scion bud did not carry any trace of wood on its under surface.

(*b*) The American method of budding, in which case the scion bud carried a thin slice of wood along with it on the under-side—the thickness of wood being in the neighbourhood of $\frac{1}{40}$in.

(*c*) The practice of lopping the seedling top, immediately after budding, at about two inches above the inserted scion bud.

(*d*) The practice of delaying the cutting of the seedling top, above the inserted bud, till such time as the scion-bud growth was first noticed.

(*e*) The practice of notching the seedling top, on the side of inserted bud and two inches above it, immediately after budding but lopping the same, at the point of notch, after the scion-buds were seen sprouting.

For convenience of reference, the above noted five treatments will be denoted hereafter by B_1, B_2, P_1, P_2 and P_3 respectively.

Study of the union between scion and rootstock

With a view to see if the thin slice of wood, attached to the bud-shield, had anything to do with improper, delayed or defective union of the scion and rootstock, 84 seedlings were selected, half of which were budded by the Indian method using sweet orange and mandarin scions and the other half were budded by the American method of budding using the same two scions (Table VII). The scion buds were inserted in each case at nine inches above the soil level and lopping of the rootstock tops was carried out immediately after budding.

To study the nature of union between scion and rootstock, and its development in case of sweet orange and mandarin scions, each budded by both the methods (Indian and American), the material collected consisted of the scion portion with an inch or so of the rootstock portion on either side. The collection of material commenced on 8 March 1940 and was repeated thereafter at weekly intervals on three occasions; that is 15 March 1940, 22 March 1940 and 29 March 1940. Again, on 1 May 1940, when the bud sprouts were about two months old, the material was collected finally for the fifth time. On each of the five occasions, two samples representing each of the four treatments (sweet orange budded by the Indian method, sweet orange budded by the American method, mandarin budded by the Indian method, mandarin budded by the American method) were collected. Thus, in all, twenty different samples were collected, and on each occasion the material was preserved in formalin alcohol (95 c.c. alcohol *plus* 5 c.c. formalin).

Three months after preserving the material, the cutting of sections was tried with a wood-microtome in the Punjab University Botany Laboratories, Lahore, but due to the heaviness of the razor, brittleness of the material, and the violent force with which the razor struck the material, the scion separated from the stock—thus defeating the object of study. The material was again allowed to remain in the preservative for three months more and again the same machine was tried without any success.

It then occurred that the material should be fixed in Celloidion but unfortunately it was not available in India and could not be had from foreign countries due to War.

Thinking that hydrofluoric acid may soften the material, one specimen was put in HF (50 c.c. HF+50 c.c. H_2O) and was allowed to remain in it for three weeks. After this, the material was thoroughly washed in water and passed through different grades of water and alcohol to absolute alcohol and through grades of alcohol and xylol to pure xylol. The material was kept for four hours in each grade. The paraffin of the melting point of 58°C. was added to xylol and the material was kept on electric bath for three weeks. The temperature of the bath was kept constant at 62°C. Occasionally small bits of paraffin were added to the xylol containing the material until the whole xylol evaporated, leaving the material embedded in pure paraffin wax. Block was prepared and section cutting was tried on microtome but this method also did not prove successful.

After this, hand microtome was tried for cutting the sections. The microtome was fixed to the table with the material and free hand sections were cut with a razor. Though it was not possible to obtain complete sections, the union between scion and stock could be studied in the partially cut sections. Some good sections were selected from each specimen and were stained in Diamond Fuchsion and Light Green. The sections were put in a dilute solution of Diamond Fuchsion for two minutes, washed in water and, after passing through rectified spirit and absolute alcohol, were put in Light Green stain in alcohol. After the red stain was replaced by the green in soft tissues, the sections were washed in alcohol and put in clove-oil for clearing and differentiation of the tissues. Sections were washed in xylol to remove clove-oil and mounted in Canada Balsam. After this the slides were dried and ringed to form permanent preparations.

Layout

The method of lay-out, adopted in these experiments, conforms to the latest field plot technique, developed and advocated by Fisher [1935] for carrying out experiments with orchard crops. The two methods of budding and the three lopping treatments were tried in six possible combinations as follows :—

B_1P_1, B_1P_2, B_1P_3, B_2P_1, B_2P_2 and B_2P_3

The rootstock seedlings were labelled to indicate the category, based on diamter measurements, and each of the six above noted treatments was tried for each rootstock category in a randomized layout. The information about the treatment given to individual seedling. was also noted on the label tied to each selected seedling. The information about the diameter and the number of seedlings in different categories, selected for various experiments, along with the coefficients of variability determined in each case, is summarized in Tables II-VII.

TABLE II

Details of the experiments on the propagation trials with mandarin (Spring 1940)

Category	Diameter of seedlings (cm.)	C.V.	No. of seedlings used for various treatments						Total
			B_1P_1	B_1P_2	B_1P_3	B_2P_1	B_2P_2	B_2P_3	
1	0·60—0·64	1·82	14	14	14	14	14	14	84
2	0·65—0·69	2·13	14	14	14	14	14	14	84
3	0·70—0·74	1·65	14	14	14	14	14	14	84
4	0·75—0·79	1·60	14	14	14	14	14	14	84
5	0·80—0·88	3·70	14	14	14	14	14	14	84
6	0·89—0·94	1·87	14	14	14	14	14	14	84
		Total .	84	84	84	84	84	84	504

TABLE III

Details of the experiments on the propagation trials with sweet orange (Spring 1940)

Category	Diameter of seedlings (cm.)	C.V.	No. of seedlings used for various treatments						Total
			B_1P_1	B_1P_2	B_1P_3	B_2P_1	B_2P_2	B_2P_3	
1	0·60—0·69	4·40	14	14	14	14	14	14	84
2	0·70—0·74	1·65	14	14	14	14	14	14	84
3	0·75—0·79	1·52	14	14	14	14	14	14	84
4	0·80—0·84	1·24	14	14	14	14	14	14	84
5	0·85—0·89	1·40	14	14	14	14	14	14	84
6	0·90—0·99	3·01	14	14	14	14	14	14	84
		Total .	84	84	84	84	84	84	504

TABLE IV

Details of the experiments on the propagation trials with mandarin repeated in Summer 1940

Category	Diameter of seedlings (cm.)	C.V.	No. of seedlings used for various treatments						Total
			B_1P_1	B_1P_2	B_1P_3	B_2P_1	B_2P_2	B_2P_3	
1	0·60—0·88	8·9	8	8	8	8	8	8	48
2	0·89—0·99	5·73	8	8	8	8	8	8	48
3	1·10—1·20	6·46	8	8	8	8	8	8	48
4	1·21—1·39	5·23	8	8	8	8	8	8	48
5	1·40—1·58	3·70	8	8	8	8	8	8	48
		Total	40	40	40	40	40	40	240

TABLE V

Details of the experiments on the propagation trials with sweet orange repeated in summer 1940

Category	Diameter of seedlings (cm.)	C.V.	No. of seedling used for various treatments						Total
			B_1P_1	B_1P_2	B_1P_3	B_2P_1	B_2P_2	B_2P_3	
1	0·70—0·74	1·8	8	8	8	8	8	8	48
2	0·75—0·79	1·8	8	8	8	8	8	8	48
3	0·80—0·84	1·5	8	8	8	8	8	8	48
4	1·00—1·10	3·9	8	8	8	8	8	8	48
5	1·11—1·20	2·5	8	8	8	8	8	8	48
6	1·21—1·30	2·1	8	8	8	8	8	8	48
		Total	48	48	48	48	48	48	288

TABLE VI

Details of the experiments on the propagation trials with sour lime (Summer 1940)

Category	Diameter of seedlings (cm.)	C.V.	No. of seedlings used for various treatments			Total
			B_2P_1	B_2P_2	B_2P_3	
1	0·60—0·64		31	31	31	93
2	0·65—0·69		31	31	31	93
3	0·70—0·74		31	31	31	93
4	0·75—0·79		31	31	31	93
5	0·80—0·83		31	31	31	93
6	0·85—0·94		31	31	31	93
		Total	186	186	186	558

TABLE VII

Details of the experiments on the anatomy and histology of union between two scions and a rootstock

Treatment	No. of seedlings budded		Total
	Sweet orange scion	Mandarin scion	
Indian method	21	21	42
American method	21	21	42
Total	42	42	84

The figures for coefficient of variability are very low, showing a close uniformity in the individuals comprising different categories in each experiment. Again, the variability between the categories themselves is also low, which means that these categories are directly comparable with one another.

Selection and preparation of bud-wood

Round, healthy and plump shoots of one season's growth were selected for propagation trials with sweet orange and mandarin bud-wood from a single tree was used in both cases and in both the seasons of budding. Scion-wood, used for sour lime (variety oval-shaped) propagation studies, was selected from several trees as sufficient wood on any single tree was not available. As much of it was cut daily as required. While removing leaves from bud-sticks, a portion of the leaf-stalk was left intact, which helped to protect the scion-bud and also helped in its handling. The bud-sticks were taken to the field after wrapping in wet hemp bag and the buds were removed by means of the sharp knife taking care that the knife always worked in the acropetal direction. Each bud, when removed, was about one inch long and had a little piece of wood attached to it on its under surface. The buds, as removed, were put in a cup containing water. The wood was removed from about half the number of buds, taking care that the germ or meristematic tissue of the buds was not injured.

Budding operation

The work of budding, which commenced on 22 February 1940, was performed exclusively by one budder. There was, therefore, no chance of variability being introduced due to human factor. For sweet orange budding, the bud-wood was collected from a tree of the Valencia Late variety. The scion used in the other plot was that of Nagpur mandarin variety. This was also collected from a single tree growing in the same orchard.

Budding started on 22 February 1940 in case of the sweet orange scion. Before budding, the leaves of the rootstock seedlings were removed up to about one foot from the ground level. Then, at a height of about nine inches from the ground level, on the northern side of the seedlings, two incisions (one horizontal and other longitudinal) approximately at right angle to each other were made with a budding knife. The bark flaps, at the junction of the two cuts, were raised slightly with the blunt edge of the knife for inserting the buds therein. Buds were inserted at this height to safeguard against gum disease infection, which usually comes from the soil. If, on the other hand, buds are inserted too high, a crooked and ugly trunk may result. The scion-buds were picked up one by one from the cup and inserted immediately from the upper side of the (T) and pushed in the downward direction for fitting into the cut. This operation was done very carefully to avoid injury to the tissues of the bud. After this, the buds were tied in position with raffia. This operation was started from the upper end of the inserted bud and finished at the lower end with a knot. The idea in inserting the scion buds on the north side was to protect them from the direct rays of the sun.

Removing the raffia

About 20 days after finishing the budding, the raffia was cut off by giving a longitudinal cut on the side opposite to the inserted bud. During this period, the scion buds were taken to have united with the stock even if no growth was visible.

Removing the stock sprouts

While examining the scion-bud sprouts, it was noticed that some buds on the rootstock portion had also sprouted. These sprouts were rubbed off without injuring the sprouts from the scion-buds.

Training the budded plants

In order to ensure a perfectly straight stem, the young sprouts were trained with stakes. When the sprouts had grown to a length of about three inches, they were tied to the stumps of rootstocks, usually left above the inserted buds. At the same time, stakes of *Saccharum sp.* (Sarkanda) were

provided to the budded plants and were fixed on the southern side,.which was in a direction opposite to that on which scion-buds were inserted. The young sprouts were trained carefully along these stakes by tying with raffia at suitable intervals. The side branches on the main shoot were not allowed to grow and, after the main shoot had grown sufficiently tall, the rootstock stumps, left at two inches above the inserted buds, were cut close to the scion shoots. After the scion shoots had grown to a length of nearly a foot and a half, the side branches were also allowed to be formed. The budlings, thus trained, became ready for transplanting after about a year.

Data collected

It has been previously stated that a good deal of numerical data were collected in connection with the selection of material for carrying out the various investigations. The data connected with the problems under study, however, were collected after the seedlings had been budded. It comprised (*a*) the number of days required for bud-break in each case, (*b*) the percentage of bud-take in each case, (*c*) the vigour of the budlings under each treatment, and (*d*) the nature and development of union between stock and scion. In collecting data on all the four aspects mentioned above, the following procedure was adopted.

Time required for bud-break in each case

In spring 1940, the budding operations in case of the sweet orange and mandarin plots were finished on 25 February 1940 and 29 February 1940, respectively. The examination of the budded seedlings in both the plots was started on 3 March 1940 in case of sweet orange budding trials and on 7 March 1940 in case of mandarin budding. Observations were made daily and the sprouting of buds was recorded in the field register by using positive and negative signs. Thus +ive sign against a seedling on a certain date would show that bud-break started on that date, whereas the —ive sign would indicate that bud-break had not commenced. In cases, where growth died out after once starting, it was necessary to add negative sign with positive previously given. Similarly, for budding trials carried out and repeated in summer 1940 in case of sweet orange, mandarin and sour lime, the bud sprout records were also taken in the same way as in spring of the same year.

Percentage of bud-take in each scion variety

In calculating the percentage of bud-take in each case, the surviving budlings only were taken into consideration and those drying out after some time due to various causes were not included. The counts for bud-take were thus made after about three months of the time of budding in each case and in both the seasons.

Vigour of budlings under each treatment

About one year after the date of budding, the budded plants were measured for diameter by Vernier callipers at points approximately two inches above the union. The total extensional growth in cm. was also recorded for each budded plant by means of the meter-rod.

Nature and development of union between scion and stock

The procedure for preserving the material, section cutting and preparation of permanent slides has been described under the section on 'Methods employed'. Microphotographs of all the permanent slides were taken with a view to study the nature and development of the union between scion and stock for all the scion species budded by the two different methods.

Presentation of results

It has been previously mentioned that the data were collected from several view-points. The mass of figures, thus accumulated, were suitably compiled for statistical calculation and interpretation of results. Such mean tables concerning the various phases of study have been excluded in the interest of brevity. After working out the statistical constants in each case, summary tables were prepared which are presented and discussed here. The various phases of study embracing the present investigations have been presented below.

Period of bud-break as affected by various propagation methods and categories of root-stocks

The results under this item of study were available for both spring and summer seasons of budding in case of sweet orange and mandarin and for summer season alone in case of sour lime scion. The results for three scion varieties are presented separately as follows :—

(*a*) *Sweet orange budding trial carried out in spring 1940 and repeated in summer 1940.* A statistical study of the mean number of days required for sprouting of sweet orange buds that were inserted in the seedlings of various categories with respect to the two methods of budding and three after-treatments is presented as follows :

TABLE VIII

Period of bud-break in case of sweet orange scion as affected by various propagation methods and categories

(a) *Methods of budding*

Method of budding	Spring 1940		Summer 1940	
	Mean No. of days taken	C.D.	Mean No. of days taken	C.D.
B_1	15·16	0·47	19·58	3·05
B_2	14·41		19·26	

(b) *After-treatments*

After-treatment	Spring 1940		Summer 1940	
	Mean No. of days taken	C.D.	Mean No. of days taken	C.D.
P_1	14·12	0·56	12·99	3·7
P_2	15·28		23·20	
P_3	14·95		22·06	

(c) *Effect of categories*

Category	Spring 1940		Summer 1940	
	Mean No. of days taken	C.D.	Mean No. of days taken	C.D.
1	14·5	0·82	19·32	5·30
2	15·9		19·66	
3	14·1		20·14	
4	14·6		17·79	
5	15·0		18·36	
6	14·6		21·24	

TABLE VIII—contd

(d) Inter-action of method with after-treatment

	Spring 1940			Summer 1940		
	Mean No. of days taken.			Mean No. of days taken		
	P_1	P_2	P_3	P_1	P_2	P_3
B_1	14·46	16·14	14·87	12·03	24·42	22·27
B_2	13·78	14·43	15·03	13·96	21·98	21·85
Difference . .	00·68 (+)	1·71 (+)	00·16 (—)	1·13 (—)	2·44 (+)	00·42 (+)
C.D.		0·82			5·30	

The following conclusions can be made from the data presented in Table VIII.

(i) In spring 1940 the mean number of days taken for bud-break by the Indian method is 15·16 as against 14·41 by the American method. This shows that the American method of budding hastened the period of bud-break by 0·75 days on the average. This difference is apparently small but the effect of both methods of budding is so consistent for all the categories that even this small difference is significant. In summer 1940 both the methods behaved alike in influencing the period of bud-break.

(ii) The mean No. of days taken for bud-break is the least under P_1 as compared with other after-treatments for both the seasons. The differences in both cases are significant showing thereby that P_1 after-treatment should be preferred to the other two in reducing the period of bud-break.

(iii) Of all the categories tried, none has increased the period of bud-break except category No. 2 in spring season of budding. It can be infered therefore that, in general, the categories have not shown any effect on the period of bud-break.

(iv) The figures in the inter-action table show that in decreasing the period of bud-break B_2 is superior to B_1 only when the after-treatment followed in both cases is P_2. In case of P_1 also, the American method has given better results over the Indian method but the difference is not large statistically. The period of bud-break is the least for the combination B_2P_1, which shows that for both methods of budding, preference should be given to P_1 with a view to decrease the period of bud-break.

(*b*) *Mandarin budding trial carried out in spring 1940 and repeated in summer 1940.* A statistical study of the mean number of days required for sprouting of mandarin buds that were inserted in the seedlings of various categories with respect to two methods of budding and three after-treatments is presented below.

TABLE IX

Period of bud-break in case of mandarin scion as affected by various propagation methods and categories

(a) *Method of budding*

Method of budding	Spring 1940		Summer 1940	
	Mean No. of days taken	C.D.	Mean No. of days taken	C.D.
B_1	18·59		23·19	
B_2	15·92	1·9	19·87	5·7

TABLE IX—contd

Period of bud-break in case of mandarin scion as affected by various propagation methods and categories

(b) *After-treatments*

After-treatment	Spring 1940		Summer 1940	
	Mean No. of days taken	C.D.	Mean No. of days taken	C.D.
P_1	16·42	2·38	13·91	8·07
P_2	17·78		22·34	
P_3	17·57		17·58	

(c) *Effect of categories*

Category	Spring 1940		Summer 1940	
	Mean No. of days taken	C.D.	Mean No. of days taken	C.D.
1	16·65	3·34	22·36	10·37
2	17·33		20·51	
3	18·52		20·85	
4	16·45		27·38	
5	17·18		16·65	
6	17·41		*Nil.*	

(d) *Inter-action of method with after-treatment*

	Spring 1940			Summer 1940		
	P_1	P_2	P_3	P_1	P_2	P_3
B_1	17·57	18·48	19·74	16·27	35 31	17·99
B_2	15·27	17·09	15·39	17·11	18·30	24·20
Difference	2·30 (+)	1·39 (+)	4·35 (+)	00·84 (—)	17·01 (+)	6·21 (—)
C.D.		3·34			11·29	

The following conclusions can be drawn from the data presented in Table IX.

(i) In spring 1940, the mean number of days taken for bud-break by the Indian method of budding is 18·59 as against 15·92 by the American method. And in summer 1940, the days required by the Indian method are 23·19 as against 19·87 required by the American method. It is clear, therefore, that American method of budding hastened the period of bud-break of mandarin by 2·67 days in spring and 3·32 days in summer. The difference is significant statistically in case of spring budding and is suggestive only in case of summer budding.

(ii) The mean number of days taken for bud-break is the least under P_1 and greatest under P_2 for both seasons of budding. In spring budding the differences are not significant but for summer budding P_1 has shown distinct superiority over P_2. In general, P_1 should be given preference to the other two after-treatments in case of mandarin budding also.

(iii) Of the various categories under trial none influenced the period of bud-break in case of spring budding. But in summer 1940, the seedlings of fifth category decreased the period of bud-break and, on the contrary, fourth category alone increased this period. All the remaining three categories have not, however, shown any effect on the period of bud-break.

(iv) The figures in the inter-action table show that the period of bud-break is the least under P_1 for both methods of budding and during both seasons of budding. However, the superiority of B_2 over B_1 lies in following the P_3 after-treatment in spring season of budding and P_2 after-treatment in summer season of budding.

(*c*) *Sour lime budding trial carried out in summer 1940.* A statistical study of the mean number of days required for sprouting of sour lime buds inserted in seedlings of various categories with respect to one method of budding and three after treatments is presented below.

TABLE X

Period of bud-break in case of sour lime scion as affected by the three after-treatments and categories of rootstock

(a) *After-treatments*

After-treatment	Mean number of days taken	Critical difference
P_1	23·50	
P_2	39·05	7·87
P_3	34·06	

(b) *Effect of categories*

Category	Mean number of days taken	Critical difference
1	29·40	
2	31·60	
3	31·92	
4	31·67	10·9
5	34·00	
6	34·70	

The following conclusions can be made from the data presented in Table X.

(i) The data in part (*a*) show that P_1 is significantly better than the remaining two after-treatments in reducing the period of bud-break in case of sour lime scion. The differences are significant even at one per cent level.

(ii) The data in part (*b*) show that root-stocks of different vigour have no influence on the period of bud-break.

Percentage of bud-take as affected by various propagation methods and categories of rootstocks

The results under this item of work were available for both spring and summer seasons of budding in case of sweet-orange and mandarin scions and summer season alone in case of sour lime scion. These results for the three scion varieties are presented separately as follows.

(*a*) *Sweet orange budding trial carried out in spring 1940 and repeated in summer 1940*. A statistical study of the percentage of take of sweet orange buds inserted in stock seedlings of various categories with respect to two methods of budding and three after-treatments is presented as follows.

TABLE XI

Percentage of bud-take in case of sweet orange scion as affected by three after-treatments and six categories of root-stock

(a) *Methods of budding*

Method of budding	Spring 1940		Summer 1940	
	Mean percentage of bud-take	C.D.	Mean percentage of bud-take	C.D.
B_1	92·1	6·72	80·6	
B_2	93·2		83·3	11·8

(b) *After-treatments*

After-treatment	Spring 1940		Summer 1940	
	Mean percentage of bud-take	C.D.	Mean percentage of bud-take	C.D.
P_1	93·4		79·2	
P_2	89·9	8·28	84·4	14·2
P_3	94·7		82·3	

(c) *Effect of categories*

Category	Spring 1940		Summer 1940	
	Mean percentage of bud-take	C.D.	Mean percentage of bud-take	C.D.
1	91·7		81·3	
2	95·2		81·3	
3	88·1		87·5	
4	93·0	11·56	77·1	20·27
5	93·9		87·5	
6	94·1		77·1	

The following conclusions can be made from the data presented in Table XI.

(i) In case of sweet orange scion, the percentage of bud-take is not influenced by the methods of budding tried in case of both the seasons.

(ii) The three after-treatments, tried in both the seasons, have not influenced the percentage of bud-take.

(iii) There is no evidence of the influene of root-stock vigour on the percentage of bud-take during both the seasons of budding.

(*b*) *Mandarin budding trial carried out in spring 1940 and repeated in summer 1940*. A statistical study of the percentage take of mandarin buds inserted in stock seedlings of various categories with respect to two methods of budding and three after-treatments is presented below.

TABLE XII

Percentage of bud-take in case of mandarin scion as affected by two methods of budding, three after-treatments and six categories of root-stock

(a) *Method of budding*

Method of budding	Spring 1940		Summer 1940	
	Mean percentage of bud-take	C.D.	Mean percentage of bud-take	C.D.
B_1	83·3	10·02	51·7	
B_2	74·1		42·3	16·93

(b) *After-treatments*

After-treatment	Spring 1940		Summer 1940	
	Mean percentage of bud-take	C.D.	Mean percentage of bud-take	C.D.
P_1	73·6		53·1	
P_2	78·73	11·54	28·1	20·52
P_3	83·75		36·5	

(c) *Effect of categories*

Category	Spring 1940		Summer 1940	
	Mean percentage of bud-take	C.D.	Mean percentage of bud-take	C.D.
1	85·7		50·0	
2	85·7		47·9	26·72
3	76·2	17·60	47·9	
4	74·4		45·8	
5	76·4		43·7	
6	73·8		Nil	

(d) *Inter-action of methods with after-treatments*

	Spring 1940			Summer 1940		
	P_1	P_2	P_3	P_1	P_2	P_3
B_1	85·8	74·4	86·5	80·0	37·5	37·5
B_2	61·4	80·0	80·9	47·5	30·0	50·0
Difference	24·4	5·6	5·6	32·5	7·5	12·5
	(+)	(—)	(+)	(+)	(+)	(—)
C.D.		17·60			29·00	

The following conclusions can be made from the data presented in Table XII.

(i) The data in part (a) show that the percentage of bud-take in case of mandarin scion can be considerably increased by following the Indian method of budding. The results for both the seasons are in favour of B_1, and the differences are high enough as compared with the critical limit.

(ii) The influence of after-treatments on the percentage of bud-take is interesting. In spring season, both P_2 and P_3 should be preferred to P_1, but on the contrary, P_1 should be given preference to others in summer season as it has given far better results in this season.

(iii) The various categories of root-stock do not materially differ from one another in affecting the percentage of bud-take. But it is evident that the thicker the stock seedling, the least the percentage of bud-take.

(iv) The figures in the inter-action table show that the Indian method of budding significantly established superiority over the American method of budding when P_1 after-treatment is followed in both cases. This is true for both the seasons of budding.

(*c*) *Sour lime buddng trial carried out in summer, 1940.* A statistical study of the percentage take of sour lime buds inserted in stock seedlings of various categories with respect to three after-treatments is presented below.

TABLE XIII

Percentage of bud-take in case of sour lime scion as affected by three after-treatments and six categories of root-stock

(a) *After-treatments* (*Summer 1940*)

After-treatment	Mean percentage of bud-take	C.D.
P_1	55·66	
P_2	23·2	15·02
P_3	35·2	

(b) *Effect of categories* (*Summer 1940*)

Category	Mean percentage of bud-take	C.D.
1	34·3	
2	40·1	
3	28·0	
4	39·4	21·39
5	42·4	
6	43·4	

The following conclusions can be drawn from Table XIII.

(i) P_1 after-treatment resulted in the highest percentage of bud-take as compared with the other two. The differences are statistically significant in each case.

(ii) Of the various categories under trial, all but No. 3 behaved alike in influencing the percentage of bud-take. The influence of No. 3 also is not significant statistically from the remaining categories.

The vigour of one-year old budded trees as affected by various propagational methods and categories of root-stock

The results under this item of work are available only for spring budding trial carried out in case of sweet orange and mandarin. The measurements of budlings were recorded a year after the

time of budding. The results for two scion varieties are presented separately both for diametrical girth and total growth as follows.

Diametrical girth and total growth of sweet orange budlings. A statistical study of the mean diametrical girth and mean total growth of the sweet orange budlings on stock seedlings of various categories with respect to the two methods of budding and three after-treatments is presented below.

Table XIV

Diametrical girth and total growth of sweet orange budlings as affected by various propagation methods and categories

(a) *Methods of budding*

Method of budding	Diametrical girth in cm.		Total growth in cm.	
	Mean girth per budling	C.D.	Mean total growth per budling	C.D.
B_1	0·840	0·05	229·5	19·16
B_2	0·792		203·7	

(b) *After-treatments*

After-treatment	Diametrical girth in cm.		Total growth in cm.	
	Mean girth per budling	C.D.	Mean total growth per budling	C.D.
P_1	0·86	0·04	224·1	23·61
P_2	0·82		221·4	
P_3	0·78		204·3	

(c) *Effect of categories*

Category	Diametrical girth in cm.		Total growth in cm.	
	Mean girth per budling	C.D.	Mean total growth per budling	C.D.
1	0·72	0·088	133·8	33·4
2	0·79		201·9	
3	0·77		205·9	
4	0·83		222·0	
5	0·83		226·2	
6	0·05		259·8	

TABLE XIV—*contd.*

Diametrical girth and total growth of sweet orange budlings as affected by various propagation methods and categories

(d) *Inter-action of method with after-treatment*

	Diametrical girth in cm.			Total growth in cm.		
	P_1	P_2	P_3	P_1	P_2	P_3
B_1	0·897	0·872	0·752	237·3	255·3	195·8
B_2	0·813	0·770	0·810	210·9	187·5	212·7
Difference . . .	0·084	0·102	0·058	26·4	67·8	16·9
	(+)	(+)	(—)	(+)	(+)	(—)
C.D.	0·088			33·4		

The following conclusions can be made from the data presented in Table XIV :—

(i) The Indian method of budding shows statistically significant superiority over the American method of budding in producing vigorous and well developed sweet orange plants.

(ii) P_1 after-treatment helped to produce vigorous and well developed plants as compared with P_2 and P_3. As regards diametrical girth the differences are statistically significant, but for total extentional growth the differences are not quite significant.

(iii) The thicker the stock-seedling the more vigorous are the plants produced on it.

(iv) The figures in the inter-action table show that in case of the Indian method of budding. P_1 and P_2 gave nearly indentical results but in case of American method. P_1 and P_3 should be preferred to produce better sized trees in the same period.

Diametrical girth and total growth of mandarin budlings. A statistical study of the mean diametrical girth and the mean total growth of the mandarin budlings, propagated on stock seedlings of various categories with respect to two methods of budding and three after-treatments is presented below.

TABLE XV

Development of mandarin budlings as affected by various propagation methods and categories

(a) *Methods of budding*

Method of budding	Diametrical girth in cm.		Total growth in cm.	
	Mean girth per budling	C.D.	Mean total growth per budling	C.D.
B_1	0·697	0·013	349·5	65·57
B_2	0·689		331·5	

(b) *Effect of after-treatments*

After treatment	Diametrical girth in cm.		Total growth in cm.	
	Mean girth per budling	C.D.	Mean total growth per budling	C.D.
P_1	0·83	0·0155	456·4	80·34
P_2	0·62		251·8	
P_3	0·62		333·5	

TABLE XV—*contd.*

Development of mandarin budlings as affected by various propagation methods and categories

(c) *Different categories*

Category	Diametrical girth in cm.		Total growth in cm.	
	Mean girth per budling	C.D.	Mean total growth per budling	C.D.
1	0·64		306·9	
2	0·69		327·1	
3	0·73	0·022	388·7	113·74
4	0·61		262·8	
5	0·73		368·3	
6	0·74		389·4	

(d) *Effect of inter-action of method of budding with after-treatments*

	Diametrical girth in cm.			Total growth in cm.		
	P_1	P_2	P_3	P_1	P_2	P_3
B_1	0·88	0·64	0·55	511·7	263·6	273·5
B_2	0·78	0·60	0·68	401·1	239·9	353·6
Difference	0·10 (+)	0·04 (+)	0·13 (—)	110·6 (+)	23·7 (+)	80·3 (—)
C.D.	0·022			113·74		

The following conclusions can be made from Table XV:—

(i) The Indian method of budding resulted in producing comparatively more vigorous trees of mandarin in the same period as compared with the American method. The differences, however, are not large enough to be significant statistically.

(ii) P_1 treatment proved significantly better than both P_2 and P_3 for producing better sized trees.

(iii) The thicker the stock seedling, the better the size of budlings produced on it. This observation was offset only by seedlings in category No. 4.

(iv) The data in the inter-action table show marked superiority of P_1 in case of both the methods of budding tried. Thus larger sized plants can be produced by either method of budding if the seedling top is cut off immediately after budding.

Nature and development of union between scion and root-stock

The material for this study was collected for the first month at weekly intervals after budding and thereafter once again when the inserted buds were two months old. The procedure for preserving the material, the cutting of sections and preparation of the permanent slides has been laid down already under the section on 'Methods employed'. The microphotographs of all the slides were taken to make a detailed study of the nature and development of union between scion and root-stock. The results for the two scions, namely sweet orange and mandarin have been presented separately as under.

Union of sweet orange buds with rough lemon root-stock. In Plate I, figs. 1, 2 is shown the course of development of union after a week from budding of sweet orange buds inserted respectively by the

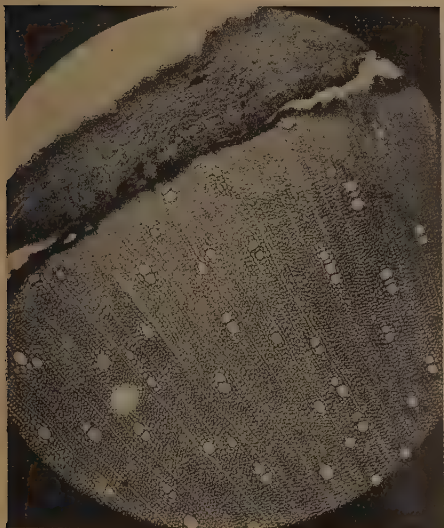

FIG. 1. Indian method

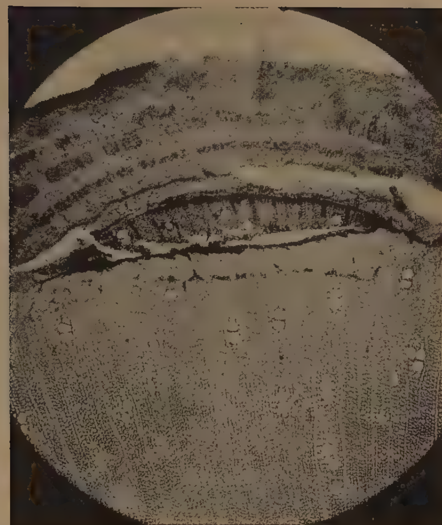

FIG. 2. American method

One week old union of sweet orange buds with rough lemon rootstock, budded by different methods of budding

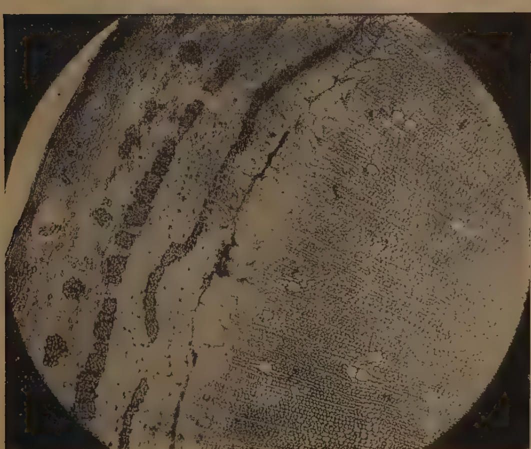

FIG. 3. Indian method

FIG. 4. American method

Two months old union of sweet orange buds with rough lemon rootstock budded by different methods of budding

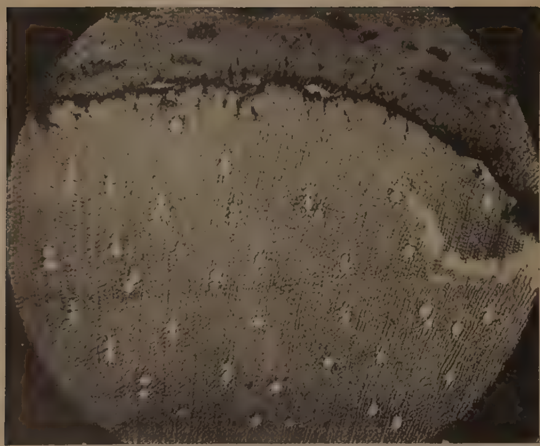

FIG. 1. Indian method

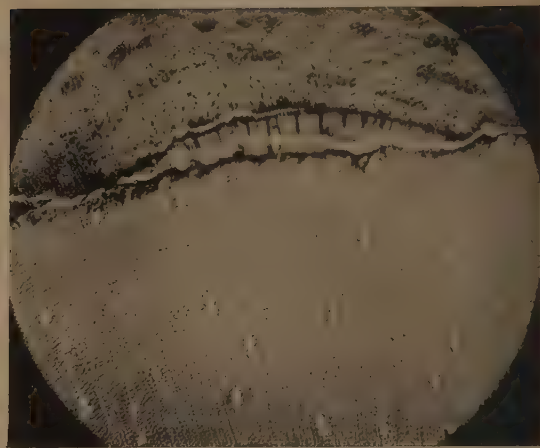

FIG. 2. American method

One week old union of mandarin buds with rough lemon rootstock budded by different methods of budding

FIG. 3. Indian method

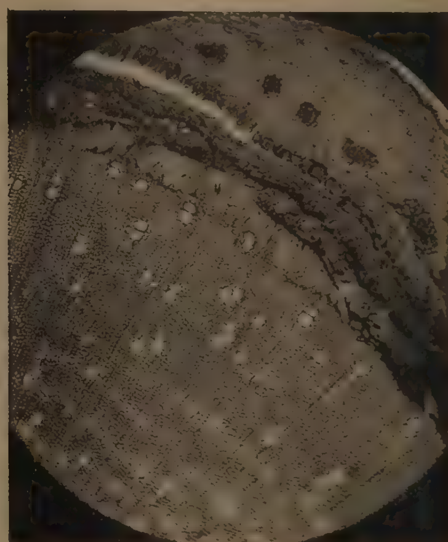

FIG. 4. American method

Two months old union of mandarin buds with rough lemon rootstock budded by different methods of budding

Indian and American methods of budding. There is slight formation of callus tissue joining the stock and scion only in the middle by the Indian method (Plate I, fig. 1) but there is no indication of such union taking place near the upper and lower ends. On the other hand, by the American method (Plate I, fig. 2) there is no indication of callus formation either in the middle or near the ends of uniting surfaces except that there is slight callus formation near such portions of the scion buds as are free from the woody tissue.

The callus formation took place two weeks after budding by Indian method at various points to provide union between scion and stock, leaving only a few gaps where callus tissue has not developed properly. On the other hand, by the American method the callus formation took place only near the ends, probably for the reason that these were free from the woody tissue. In other words, the woody tissue has served to inhibit the formation of callus thereby delaying the proper union between scion and root-stock.

Three weeks after budding, the formation of callus by the Indian method took place over the entire surface and the initiation of small celled tissue occurred both from the scion and the root-stock. On the other hand, by the American method the formation of callus is interrupted at several points and the small celled tissue developed only from one side, viz. the root-stock. In case of four weeks old material prepared by Indian method is noticed the complete union between scion and root-stock. The tendency to form vascular bundles on the scion bud is also noticed. The small celled tissue from both the uniting sides has inter-mingled at various points by breaking the callus. On the other hand, in case of material of the same age prepared by American method the union between the scion and root-stock is not complete, but that it took place at several points. The small celled tissue has also developed at several points but no intermingling of the same has resulted.

In case of the two months old material prepared by the Indian method, (Plate I, fig. 3) is seen the complete intermingling of tissue. The differentiation of vascular tissue has also completed in the scion portion. Thus the union between scion and root-stock may be said to have completed after two months. In case of material of the same age, prepared by the American method (Plate I, fig. 4) there is an alround retardation in various processes leading to the complete formation of union. Thus the intermingling of tissue has not taken place at several points. The formation of vascular bundles had started but it has, by no means, completed as yet.

Union of mandarin buds with rough lemon root-stock. In Plate II, figs. 1 and 2 is shown the course of development of the union of mandarin buds with rough lemon root-stock after a week from budding. The material shown in Plate II, fig. 1 was budded by the Indian method and that shown in Plate II, fig. 2 was budded by the American method. In Plate II, fig. 1, the formation of callus is seen at many points excepting two or three gaps, whereas in Plate II, fig. 2, the tendency for callus formation does not exist at any point except at one extremity.

In case of two weeks old material prepared by the Indian method, the callus tissue between the scion and root-stock has been formed completely. There is also a tendency towards the formation of small celled tissue. In case of material of the same age prepared by the American method on the other hand, the formation of callus has taken place only at such points as are free from the woody tissue. However, a tendency for the formation of vascular bundle in the scion is imminent.

In case of four weeks' old material prepared by the Indian method, intermingling of the tissue has taken place and formation of vascular tissue in the scion has also commenced.

On the other hand, in case of material of the same age prepared by the American method, even the small celled tissue has not developed completely on the side of scion probably due to the presence of the strip of wood. The formation of vascular bundles in the scion in this case, however, is far advanced as compared with the Indian method.

Two months after budding, the union by the Indian method (Plate II, fig. 3) appeared to be comparatively better than by the American method (Plate II, fig. 4). By the Indian method, the union was complete in every respect after two months and the differentiation of vascular bundles in the scion had also taken place. By the American method on the other hand, the inter-mingling of the small celled tissue had not taken place completely in an equivalent period of two months but the vascular bundles in the scion were completely formed and were clearly visible.

Discussion

The Indian versus *the American method of budding*

So many important issues have been raised by this study that it is difficult to give them all an adequate discussion within the limits of the present paper. The observations made and the data reported in the foregoing pages lead to the conclusion that the Indian method of budding should be preferred to the American method, in case the scion buds are free of thorns. But in the event of the thorns being present in close proximity to the scion buds, the method to be used must necessarily be the American one, as any effort to remove the buds, clean of the wood, as is done in case of the Indian method, would fail because the meristamatic tissue of the buds would be punctured by the thorns thereby lowering the efficiency of take.

The above conclusion is based on the study of several factors involved in the successful technique of nursery tree propagation of sweet orange and mandarin, as for instance the period of bud-break, the percentage of bud-take, the nature and development of the scion bud union and the vigour of budlings. The results showed that whereas the presence of wood under the scion-bud might serve a useful purpose in stimulating early growth of inserted scion buds, this, on the other hand, had not influenced the bud-take. It may be noted that the American method of budding was quite unknown to the Indian nurserymen till only a decade back when it was first put into practice at Lyallpur for propagating such important citrus fruits as the newly introduced grape-fruit and the old Indian favourite the *Kaghzi nimboo* or sour lime.

Coming to the relatively more important issue, viz. the percentage of bud-take, it is clear that the two methods of budding should now be regarded as equally efficient as both did not materially differ from each other in influencing the 'take' of buds. This is in conformity with the results obtained previously in the Punjab (Lal Singh, 1936). The data further suggest that preference, if any, should be given to the Indian method of budding so far as the propagation of mandarin trees is concerned.

On comparing the nature and development of bud-union, as taking place between the scion and root-stock by these two methods of budding, it is at once clear that the union by the Indian method not only materialized in a shorter period but it was also more perfect as compared with that obtained by the American method. Even after two months of budding, the union by the American method remained incomplete due mainly to the presence of wood portion which did not allow the cambium tissues of stock and scion to come into close proximity and establish the union. These results corroborate those obtained by Mendel [1936] who in summing up the results of his investigations remarked 'For all practical purposes, the budding in citrus should be done without wood'.

In conclusion, therefore, it appears that under conditions where both methods of budding have equal chance of being adopted and where the discrimination in their use lies in individual preference only, the Indian method should be preferred as, in practice it would be possible to raise bigger sized nursery trees in the same period by this method as compared with the American method.

Influence of after-treatments

It has been conclusively proved that under conditions of the present investigations, P_1 (lopping immediately after budding) produced outstandingly the best results as compared with the other two treatments. It reduced the period of bud-break in case of all the three scions, it exhibited a marked influence on tree size for both the scions and it proved to be singularly the best treatment for significantly increasing the percentage of bud-take in case of *Kaghzi nimboo*, although in this particular respect its influence on the other two scions is not well marked. In general, therefore, the superiority of this treatment of lopping over the other two, has been clearly established. Naik [1939] recorded similar influence of this treatment on the period of bud-break but for some unexplained reasons the shoots starting early growth in his trials ultimately lagged behind in size and development.

It is obvious, therefore, that the kind of treatment imparted to the stock seedling top after inserting the scion-bud plays an important role in precisely determining the various indices of growth. This conclusion based as it is on the evidence presented in this paper is a point of considerable practical

and theoretical importance. On the one hand, it establishes the superiority of a particular treatment in nursery production technique and on the other it lends support to the hypothesis adumbrated by Loeb [Summers, 1924]. It is, therefore, clear that whatever the explanation in favour of P_1, the stimulation for the growth of a newly inserted scion-bud is no concern of the portion of root-stock above it. In fact, the delay caused in lopping the seedling top adversely affected this stimulus. It is often said that leaving the stock seedling intact along with leaves after bud-insertion is advantageous and essential for getting desirable results but the data here reported have proved beyond doubt that this view is highly fallacious.

Influence of the vigour of stock seedlings

Root-stock seedlings of six different categories selected with regard to vigour, were budded with each of the three scions namely sweet orange, mandarin and sour lime. The results showed that the vigour of root-stock had no influence on the period of bud-break and the percentage of bud-take. There was, however, an indication that increased vigour of root-stock seedling might adversely affect the 'take' in case of mandarin, but in case of the other two scions no adverse effect of this kind was experienced.

The influence of root-stock vigour on the development of scion-bud growth is most marked. Thus after a year from budding, the sweet orange and mandarin trees were bigger in size on the comparatively more vigorous stock seedlings used. In other words, when the thickness of root-stock, at nine inches above soil level, ranged between 0·6 and 1·6 cm., the thicker the stock seedling, the better sized the nursery tree. This response of bud-growth, however, had not been surprising in view of the fact that initial increased vigour of root-stock must eventually express itself in increased size of budling on account of its having a comparatively larger root-system.

It is, therefore, concluded that the vigour of root-stock, used in these trials, influenced neither the period of bud-break nor the percentage of take of buds. This, on the other hand, significantly increased the size of budlings—the increase in size being directly proportional to the vigour of stock seedlings used.

Influence of the seasons of budding

It now remains to discuss if the conditions obtaining in the two seasons of budding had any influence on the growth indices relating to nursery tree propagation. In this connection it should be noted that this information was available for bud-break and bud-take in case of two scions namely sweet orange and mandarin and results on the number of days taken for bud-break and the percentage of bud-take were in favour of spring budding for both the scions. This suggests that the activity of cell sap for propagation was better in spring than in the summer season.

It may be added that the growth of bud sprouts was arrested with the approach of winter which followed soon after the season for summer budding was over. Other disabilities usually connected with the summer season of budding are (a) showers of rain which considerably lower the take of buds and (b) the severe frost of winter which may kill young bud growths of summer budding.

It is, therefore, evident from the above that spring season should be preferred, as far as possible to the summer season for budding purpose.

Summary and conclusions

(1) A study of the propagation methods with three citrus species namely sweet orange, mandarin and sour lime was made in which two methods of budding and three after-treatments were compared in relation to six vigour categories of stock seedlings.

(2) The two methods of budding proved equally efficient so far as the take of buds in case of sweet orange was concerned. In case of mandarin budding trial, the results were appreciably in favour of the Indian method but the differences produced by the two methods were not statistically significant.

(3) Other things being equal, it was possible to obtain bigger sized nursery trees of sweet orange and mandarin by the Indian method as compared with the American method.

(4) The Indian method of budding resulted in early and complete development of union between scion and root-stock as compared with the American method.

(5) The practice of lopping the stock seedling top immediately after budding proved significantly superior, in all respects, to the other two practices in case of all the three scions under study.

(6) The increase in the size of budlings was directly proportional to the vigour of stock seedlings used. There was, however, no influence of stock vigour on the period of bud-break and percentage take of buds for all the three scions tried.

(7) The conditions obtaining in spring season proved more favourable to decreasing the period of bud-break and increasing the take of buds than those in the summer season.

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A NOTE ON THE PREDICTION OF SPINNING VALUE OF GAORANI (BANI) COTTONS

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It is well known that one of the most important factors in determining the quality of cotton is the spinning performance of its lint which is correctly estimated only by carrying out spinning tests under controlled conditions and expert supervision. Such tests, however, are both expensive and time-consuming. So far as a cotton breeder is concerned, it is a matter of utmost importance for him to know from fibre tests carried out on small samples, the probable spinning performance of his selections at as early a stage as possible, so that he may confine his attention to the desirable strains. This would save a large amount of labour, money and time that may be spent on such strains as may prove unsatisfactory from the spinning point of view at a later stage. Apart from the breeder, the consumer of cotton is also deeply interested in this problem, since he is anxious to purchase such cottons in the market as would suit his spinning requirements, but he has hardly the time to undertake actual spinning tests before making his final selections.

In view of these reasons, both cotton breeders and buyers are often constrained to base their judgement of spinning value on the fibre properties of the material presented to them. It is generally believed that the spinning performance of a cotton is closely related to the length, fineness and strength of its fibres, and, as such, both breeders and buyers employ their own methods for estimating these characteristics. It is largely on the basis of his estimate of these factors, derived from his practical experience, that a buyer purchases cotton of different types for the mills. Similarly, a breeder makes a quick determination of the values of these fibre properties and forms his judgement of the probable spinning value of his material. These rough and ready methods are, however, attended with errors of personal judgement, and as such can only be regarded as approximately correct.

Previous work

On account of the importance of this problem to cotton breeders, traders and consumers, many research workers have tried in the past to evolve formulae for the prediction of the spinning value of cotton from its fibre properties. Nazir Ahmad [1941] reviewed the position in regard to Indian cottons and pointed out that although considerable progress had been made in the last 20 years, yet there was scope for improving the efficiency of the existing prediction formulae.

The first prediction formula for Indian cottons was given by Turner and Venkatraman [1934] as a result of their studies on the fibre properties of 95 samples of standard Indian cottons. It was as follows:

$$X_1 = 75{\cdot}4\ X_2 - 79{\cdot}5\ X_3 - 22{\cdot}8 \qquad (1)$$

where X_1 = Highest standard warp counts,
X_2 = Mean fibre length (inches)
X_3 = Fibre weight per inch (10^{-6} oz.)

It was pointed out by them that, when both fibre length and fibre weight per inch were taken into account, the prediction formula agreed with actual results within 10 per cent in 44 cases out of 100 and within 20 per cent in 76 cases out of 100.

Subsequent to the above investigations, the technique of determining fibre weight per inch underwent a change in the Technological Laboratory, Matunga, and, as such, it was deemed necessary to work out the above formulae on the basis of new records for fibre weight per inch. As a result of studies on 153 samples, Nazir Ahmad [1941] evolved the following formula for predicting the spinning performance of Indian cottons on the basis of the above mentioned two major fibre properties:

$$X_1 = 78{\cdot}9\ X_2 - 79{\cdot}2\ X_3 - 24{\cdot}8 \qquad (2)$$

The agreement of the predicted values on the basis of this formula and the actual values was within 10 per cent in 44 cases out of 100 and within 20 per cent in 74 cases out of 100.

Nazir Ahmad [1941] further stated that work in this connection was being continued by dividing the Indian cottons into four major groups, viz. (i) inferior strains, (ii) superior Indian strains, (iii) exotic strains, and (iv) strains peculiar to the Gujarat tract. Separate prediction formulae have been worked out for each group on the basis of their fibre properties which give a much better agreement with the actual tests.

It will be noticed that the above formulae have been obtained by grouping Indian cottons belonging to different species more on the basis of their physical properties than on their biological affinities. It was, therefore, felt worthwhile to find out whether grouping cottons on the basis of their botanical classification might not improve the efficiency of the prediction formula for certain classes of cottons.

Hutchinson and Ghose [1937] classified the genus *Gossypium* on the basis of the evolutionary trends, etc., and showed that the Bani (Gaorani) cottons of Hyderabad State were quite different from the north Indian arboreums belonging to the class *G. arboreum* var. *neglectum* forma *bengalensis*. Since the results of fibre and spinning tests, carried out on a large number of samples at the Technological Laboratory, Matunga, were available, an attempt has been made in this paper to study the regression of the fibre properties on the spinning value and to evolve the prediction formulae for cottons belonging to this class.

Prediction of spinning value of Gaorani cottons

During the period 1932-1941, 111 samples of Gaorani (Bani) cotton belonging to the group *G. arboreum* var. *neglectum* forma *indica* were tested for their fibre properties and spinning performance in the Technological Laboratory, Matunga. The available data has been utilized to evolve a prediction formula for these cottons. Accordingly, correlation coefficients were calculated between (1) mean fibre length (inch), and (2) mean fibre weight per inch (10^{-6} oz.) on the one hand and the actual values of standard warp counts on the other : the results obtained are given in Table I.

A study of the mean fibre length data of these 111 samples showed that a large number of them covered a small range of mean fibre length, and as such it was considered desirable to see if better results would be obtained by omitting the results of 18 samples. However, the new values thus obtained (Table I) did not differ significantly from those obtained by taking all the 111 samples. This feature indicates the homogeneous nature of the group.

Table I

Correlation coefficients between mean fibre length and mean fibre weight

Correlation coefficients between		For 111 Gaorani samples	For 93 Gaorani samples
H. S. W. C.	r_{12}	+0·343	+0·361
Mean fibre length (inch)	r_{13}	—0·653	—0·673
	r_{23}	—0·026	—0·024
Mean fibre weight (10^{-6} oz.)	$r_{13\cdot2}$	—0·686	—0·712
	$r_{1(23)}$	0·730	0·756

Table II gives the comparative values of the above correlation coefficients with those obtained by Turner and Venkatraman and Nazir Ahmad for the Indian cottons taken collectively, i.e., irrespective of the biological grouping.

TABLE II

Correlation coefficients between highest standard warp counts and fibre length and mean fibre-weight per inch

Between highest standard warp count	Turner and Venkatraman: 95 samples standard Indian cottons	Nazir Ahmad: 153 samples standard Indian cottons	Gaorani samples 111
Fibre length	+0·87	+0·89	+0·34
Fibre weight per inch	—0·80	—0·83	—0·65
Fibre weight and fibre length	+0·92	+0·91	+0·73

It will be seen from the above results that the correlation coefficients total, as well as multiple, are lower for the Gaorani cottons than for the whole set of standard Indian Cottons. Furthermore, while the correlation coefficients between the highest standard warp counts and mean fibre length and mean fibre weight per inch are nearly equal for the standard cottons, the fibre weight per inch appears to be more important in determining the spinning performance of Gaorani strains than the mean fibre length. This may be an inherent feature of these cottons or it may be due to the small spread of the values of mean fibre length for a large number of the Gaorani samples.

Prediction formula for Gaorani cottons based on the values obtained for 111 Gaorani samples has also been worked out and is found to be as follows :

$$X_1 = 65{\cdot}37\ X_2 - 251{\cdot}98\ X_3 + 19{\cdot}18 \qquad (3)$$

where X_1=H.S.W.C.

X_2=Mean fibre length (inch)

X^3=Mean fibre weight (10^{-6} oz.)

Comparing the actual values of H.S.W.C. obtained for these samples with those predicted on the basis of the above formula it has been found that the agreement within 10 per cent was in 47 cases out of 100 and within 20 per cent in 82 cases of 100. The efficiency of the above formula as compared with those published recently for the India cottons is shown in Table III.

TABLE III

Agreement between actual spinning values and those from formulae for 111 Gaorani strains

Formula	Percentage of samples for which actual H.S.W.C. does not differ from predicted by more than: 10 per cent	20 per cent
X_1=78·9 X_2—79·2 X_3—24·8 (Nazir Ahmad, 1941)	34	68
New formula (in course of publication)	42	72
X_1=65·37 X_2—251·98 X_3+19·18 (proposed for Gaorani cottons)	47	82

It will be seen that as compared with the older formula the formula given above is likely to be of greater use for predicting the spinning performance of Gaorani (Bani) cottons on the basis of their mean fibre length and mean fibre weight (10^6—oz.)

ACKNOWLEDGEMENT

The work, both at Matunga and of Hyderabad Cotton Research (Botanical) Scheme, was carried out from the funds of Indian Central Cotton Committee.

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ABSORPTION POWER OF PLANT MATERIALS

By L. D. Mahajan, M.Sc., Ph.D., F.Inst.P., F.R.S.A., Professor of Physics, Mahendra College, Patiala

(Received for publication on 22 April 1946)

(With two text-figures)

SOME years ago, Ramdas and co-workers [1938, 1939] investigated the phenomenon of exchange of moisture between the air layers near the ground and substances like the soils, plant leaves, seeds, etc. exposed to the atmosphere. They dealt with the grains of wheat, paddy, *bajri*, *jowar*, etc. It was observed that the plant materials exchange moisture with the atmosphere sourrounding them. The moisture content in them was maximum at the minimum temperature epoch, and minimum at the maximum temperature epoch. But now the author has studied the absorption power of the plant materials, such as Patiala chillies, their seeds, cover, wood and leaves in their natural forms as well as their powders. The effects of their age, the percentage of humidity of the surrounding air, the time and the other physical conditions on their absorption power have also been studied. Their absorption power has been compared with those of the soils and other plant materials, and some interesting results have been found.

Classifications

Patiala, the capital of Patiala State, is one of the best centres of large production of chillies. The chillies of this part of the country have been divided according to their physical properties, into four classes, namely, PT1, PT2, PT3, and PT4.

(i) *PT1*. These chillies are long, thin, and yellow. Their length varies from about 7 cm. to 9 cm. and diameter from about 0·5 cm. to 1·0 cm.

(ii) *PT2*. They are long, thin, and red. Their length varies from about 7cm. to 9 cm. and diameter from 1·0 cm. to 1·5 cm.

(iii) *PT3*. They are not very long, but are thick and red. Their length varies from about 6 cm. to 7 cm., and diameter about 1·5 to 2·0 cm.

(iv) *PT4*. They are dwarf and red. Their length varies from about 3 cm. to 3·5 cm., and diameter from about 1·5 cm. to 2·0 cm.

The hill chillies of Patiala State were also examined. They are divided into two classes, i.e. the big and the small ones.

(i) *Big chillies*. Their diameter varies from 3 cm. to 8 cm. and length from 3 cm. to 10 cm. Their cover is comparatively much thicker. They are much less bitter than the others and are either green or red.

(ii) *Small chillies*. They are small in size. Their length varies from 3 cm. to 5 cm. and diameter from 0·5 cm. to 1·5 cm. Their cover is thin. They are very bitter and are generally red.

Apparatus

In order to study the hygroscopic properties and absorption power of the chillies, the air dried chillies in natural form were kept in glass chamber wherein the relative humidity could be altered, according to the requirements. For this purpose, the author [1940] used his old apparatus which he had devised for the study of absorption of moisture by soils from the moist air. In each case the period of exposure to the moist air was 24 hours.

Method

The power of absorption of the substances was calculated in percentage for maximum increase of humidity. The following formula was used:

$$\text{Power of absorption} = \frac{W \times 100}{W}$$

where w is the increase in weight of the substance for maximum change of humidity, and W is the initial weight of the substance at 0 per cent humidity.

OBSERVATIONS

By the use of this apparatus, the following observations (Table I) were recorded. Table I shows percentage of increase of weight of Patiala chillies by absorption of moisture from the moist air for maximum change of humidity of the surrounding air but other conditions remain the same.

TABLE I

Percentage of increase of weight of Patiala chillies by absorption of water from moist air

Material	Quality	Increase in percentage of humidity	Percentage of absorption power
Chillies PT1	Fresh	0 to 100	26·0
,, PT2	,,	,,	27·0
,, PT3	,,	,,	27·5
,, PT4	,,	,,	27·4
,, PT3	One year old	,,	7·0
,, PT4	,,	,,	5·0
Chillies wood	Fresh	,,	10·0
,, leaves	,,	,,	14·0
,, wood	Powder	,,	12·0
,, leaves	,,	,,	24·0
Hill chillies (big)	Fresh	,,	30·0
,, ,, (small)	,,	,,	28·0

In order to study whether absorption of moisture is mainly due to the cover of the chillies or their seeds, the experiments were performed with the same apparatus. The observations are given in Table II which gives the percentage of increase in weight of the seeds and the cover of the chillies by absorption of moisture from the surrounding air, when the relative humidity of the surrounding air increases from 0 to 100 per cent the other conditions remaining the same.

TABLE II

Percentage of increase in weight of seeds and cover of chillies by absorption of moisture from surrounding moist air

Material	Part	Increase in percentage of humidity	Percentage of absorption power
Patiala chillies	Cover	0 to 100	31·2
Hill chillies	,,	,,	35·0
Patiala chillies	Seeds	,,	19·6
Hill chillies	,,	,,	15·2

DISCUSSION OF RESULTS

Table I indicates that the chillies absorb moisture from the surrounding air when they are exposed to it. They behave like other plant materials, such as, wheat, *jawar*, paddy, etc., which exchange moisture with the atmosphere surrounding them. A comparison of the results obtained by Ramdas and co-workers [1938, 1939] with the observations given above in Table I shows that the chillies absorb much more moisture from the surrounding air than most of the other plant materials. The average maximum amount of moisture which the chillies can absorb is about 27 per cent. It is very high power when compared to other various kinds of plant materials, such as, grains of wheat, *jawar*, paddy, cereals, etc., and their leaves.

The comparison indicates that the chillies behave like soils. The dry plant-materials of the chillies exchange moisture with surrounding atmosphere like the soils, and have higher absorption power than that of the soils which have been already studied by the author [1940] in one of his previous papers. The absorption power of the wood is much less than that of the leaves, and the leaves have much less power than the chillies.

The powder of the chillies is very hygroscopic in character. Its hygroscopic power is higher than that of chillies in natural form. The hygroscopic power of the powder of the wood of the chillies is 2 per cent more than that of its wood. Similarly the hygroscopic power of the powder of the leaves is almost double than that of its leaves in natural form. Thus the powders of the plant materials are much more hygroscopic than the corresponding plant materials in natural form. The material produced by crushing of the fresh young plants has been found to be a better absorber of moisture than that of the old and well grown up plants. The powder of the seasoned wood has very little absorption power.

This seems an important result for it shows that the finely powdered dry plant materials produced by crushing of the young plants, preferably the leaves, increases the power of absorption of the soils when mixed with soils. It reduces the frequency of watering the soil, and thus may reduce the cost of irrigating the land. It may also help in dry farming. The powder of the cow dung cakes serves the same purpose as well. This result has already been discussed by the author [1942] in one of his previous papers.

Table I indicates that the maximum amount of moisture absorbed by the chillies varied slightly, i.e. from 25 per cent to 28 per cent. The chillies PT3 and PT4, which are thick, absorb more moisture than the others. Thus the thick covering absorbs more moisture than the thin ones.

The same table further shows that the chillies after about one year have very much less absorption power than when they were fresh. Thus the age of the chillies affects their absorption power. The older they are, the less is their absorption power.

Table II represents that the cover of the chillies has about twice the power of absorption of their seeds. The cover which is very delicate and soft, absorbs more moisture than their seeds which are hard in texture and heavy in weight. Thus the cover of the chillies is most hygroscopic and the wood the least.

The cover of the big hill chillies is much more hygroscopic than that of the chillies of the plains.

It is further found that absorption of moisture increases with the increase of humidity of the surrounding air. This result is similar to that of the soils. The relation is not exactly linear. The rate of increase of weight by absorption of moisture is heigher in the beginning than at the end.

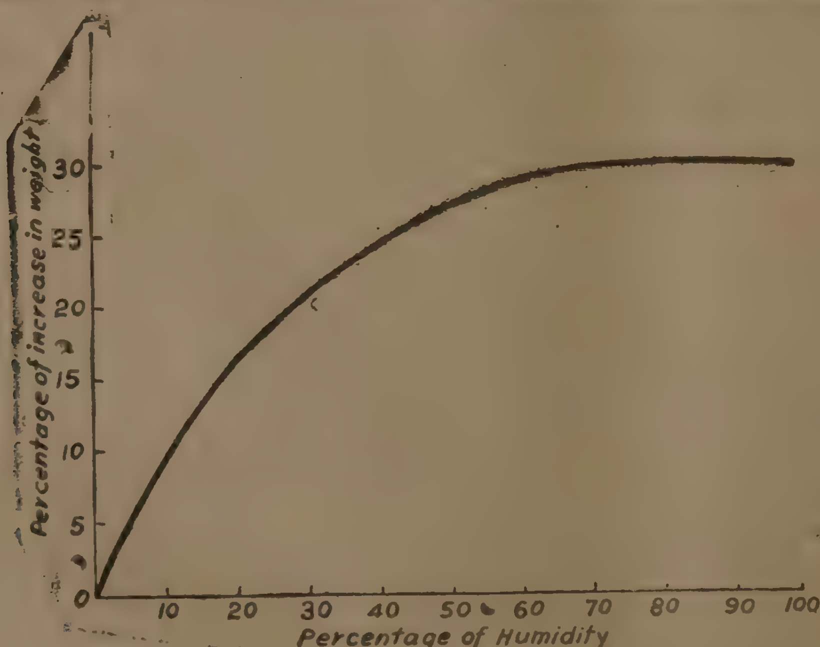

Fig. 1.

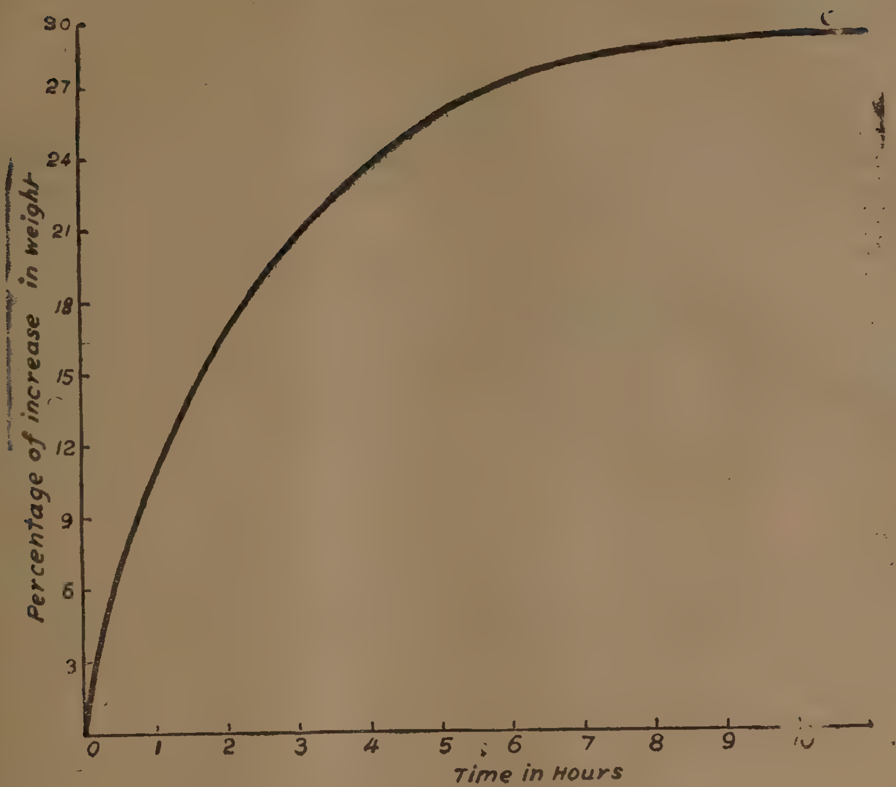

Fig. 2.

The rate of increase of weight due to the absorption of moisture with respect to time was also studied. It was found that this rate is not regular, but decreases with time. Figs. 1 and 2 show the general relation between the amount of absorption of moisture and time of exposure. The relation is not linear but logarithmic, like that of the soils.

The following conclusions have been derived from the above :

(i) The amount of moisture absorbed by the chillies varies according to their variety and the locality of their growth. The plant materials of the hills having high humidity are more hygroscopic than those of the plains.

(ii) The thick chillies absorb more moisture than the thin ones.

(iii) The power of absorption of the cover of the chillies is about twice that of their seeds.

(iv) The absorption power of wood is much less than that of the leaves and the absorption power of the leaves is less than that of the chillies.

(v) The powdered plant material is more hygroscopic than the plant material in natural form.

(vi) The chillies like the other plant materials behave like the soils, but they have higher power of absorption than the soils and some of the other plant materials, such as grains of wheat, paddy, *jawar* and *bajri*.

(vii) The absorption increases with the increase of relative humidity of the surrounding air.

(viii) The rate of absorption decreases with time. It is higher in the beginning than at the end.

(ix) The dry finely powdered plant materials produced by crushing of the young plants, when mixed with soils, increases their power of absorption. Thus it may reduce the frequency of irrigating the land, and may also help in dry farming.

(x) The age of the plant material decreases its absorption power. The older the material the less is its absorption power.

ACKNOWLEDGEMENTS

The author is indebted to Dr L. A. Ramdas for some of his reprints which he had so kindly presented to me for reference work. The author is also grateful to His Highness' Government, Patiala, for providing facilities to carry out their investigations in the Physics Research Laboratory, Mahendra College, Patiala.

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SELECTED ARTICLE

DEODORIZATION OF SYRUP MADE FROM KHANDSARI MOLASSES AND GUR*

By J. G. Shrikhande and Ram Dev, Organic Chemistry Department, Imperial Institute of Sugar Technology, Cawnpore

(With one text figure)

In view of the shortage of sugar, several enquiries were made by the manufacturers of syrups and aerated waters as to whether gur syrup could conveniently be made use of instead of sugar in this trade after in some way removing the gur odour. The typical gur odour or the aroma is mainly due to the presence of an essential oil in addition to other volatile organic bodies produced in gur due to micro-organic and enzyme activity during its storage. Caramel also to a certain extent affects the odour and also the taste. On purely chemical considerations the essential oil and volatile organic bodies like alcohol, acetone and low boiling organic acids could be removed by a current of steam. Preliminary experiments sweeping these bodies away from a gur syrup by a current of steam in the usual way gave some promising results. The results achieved by applying the usual method of steam distillation with some modification and chemical treatment to give syrup from gur and Khandsari molasses devoid of all gur aroma and flavour quite comparable to sugar syrup are embodied in this communication.

Experiments

I. *Khandsari molasses.* 600 gm. of molasses after dilution with about 100 c.c. of water were shaken with nearly 6 gm. of kaolin for one hour and filtered. Kaolin removed some of the odour along with other adsorbable impurities. The filtrate was then steam distilled for nearly five hours. The distillate was collected to examine its contents. Table I summarizes the tests both in the distillate and the steamed syrup.

Table I

Physicial and a few chemical properties of the steamed molasses and distillates

	Colour	Odour	Reaction to litmus	pH	Titrable acidity
(1) Steamed molasses . .	Dark	light molassic	No marked change	6·80	(Gm. NaOH per 1000 c.c. distillate)
(2) Molasses steamed in presence of kaolin	,,	,,	,,	7·10	..
(3) Molasses steamed after kaolin, treatment	,,	,,	Acidic	5·50	..
Corresponding distillates					
(1) Distillate	Light orange	Penetrating	Acidic	4·40	0·135
(2) ,, ...	,,	,,	,,	4·70	0·128
(3) ,, ...	,,	,,	,,	4·67	0·128

All the three distillates decolourized acid permaganate and gave a red colouration with ferric chloride indicating the presence of aldehyde and acetic acid.

The speed of distillation was considerably improved by applying a gentle section. The quantity of distillate which took five hours to collect could now be collected within an hour; this amounts to a saving in the steaming process.

* Reprinted from the XIV Proceedings Part II of the Sugar Technologists Association of India.

Effect of sulphite during steaming of Khandsari molasses on the odour of final syrup

From previous experience connected with the effect of sulphur dioxide on the colour of edible syrup from Khandsari molasses (1) it was considered desirable to see if sulphite had any direct effect on the colour and aroma of the steamed molasses. In order to test this sodium sulphite was added at the rate of 1 per cent on the weight of molasses to be steam distilled. The results are given in Table II.

TABLE II

Effect of sodium sulphite on steamed molasses

	Colour	Odour	pH
(1) Steamed molasses	Deep red	Molassic	Over 8·5
(2) Steamed molasses with Na_2SO_3	,,	Sweet like cane juice	Over 8·5
(3) Steamed molasses with Na_2SO_3 after kaolin treatment	Reddish	,,	8·5
Corresponding distillates			
(1) Distillate	Yellow orange	Pungent	4·4
(2) ,,	Deep orange	Less pungent	5·4
(3) ,,	Yellow orange	(1)	3·4

Results in Table II clearly indicate that sulphite during steaming effected the bodies responsible for the aroma of Khandsari molasses as the steamed molasses with sulphite treatment developed finally a sweet cane juice smell devoid of any molassic odour. It is possible that the essential oil responsible for the typical aroma was reduced by the sulphur dioxide produced from the added sodium sulphite. The colour too appears to have been bleached by the sulphur dioxide.

The steamed molasses was then treated with activated char and filtered through a layer of kaolin. Sulphur dioxide was then bubbled through the filtrate to effect further improvement in the colour of the syrup which was finally concentrated on a water bath to 82^0 Brix. The final syrup had a pleasant odour and a sweet taste unlike the molasses.

II. *Gur*. Gur was also treated on similar lines as the khandsari molasses to give deodorised syrup. The effect of direct steaming, after treatment with kaolin and subsequent steaming in presence of sulphite was the same as in the case of molasses. Table III contains some selected data.

TABLE III

Effect of different treatments and steam distillation on the odour of gur syrup

	Colour	Odour	pH
1. Steamed gur syrup	Red	Light gur	8·9
2. Steamed gur syrup with Na_2SO_3	Light red	Sweet cane juice	8·5
3. Steamed gur syrup with Na_2SO_3 after kaolin treatment	,,	,,	8·5
Corresponding distillates			
1. Distillate	Yellowish	Acrid and gur odour	3·4
2. ,,	Almost colourless	Almost odourless	4·5
3. ,,	,,	Odourless	4·5

It is clear from these tests that kaolin treatment followed by steam distillation in presence of sulphite completely deodorizes the syrups made from Khandsari molasses and gur. The *pH* values

of the steamed syrups and the corresponding distillates show that the acids accumulating during storage of gur and which are injurious to health are also removed by the same process.

After establishing that deodorized syrups are possible from Khandsari molasses and gur, it became necessary to study in some detail the effect of steaming for different periods on inversion of sucrose in the parent body, economics of the whole process and a few other factors connected with syrup manufacture. Accordingly experiments were conducted on gur to finalize the process as follows :

In the process adopted so far the sequence of treatments was (1) steaming, (2) sulphur dioxide treatment, and (3) concentration of the dilute syrup. All the three treatments necessarily cause inversion. To what extent inversion occurs is contained in Table IV.

TABLE IV

Inversion after each operation in deodorisation

(Results expressed on 100 gm. dry gur)

	In gur	In syrup after 1½ hr. steaming	After SO_2 treatment	Final syrup
Invert sugar	10·78	11·26	15·34	36·55

Inversion on steaming for 1½ hours is therefore almost negligible. Whatever inversion therefore occurs takes place during concentration to obtain the final syrup. This is of course due to the presence of sulphur dioxide.

Effect of different lengths of time of steaming on inversion

The results of this experiment are represented graphically in Fig I. It indicates that maximum inversion occurs during 1½ hours steaming. Any further steaming is therefore not advantageons from the point of view of inversion and deodorization.

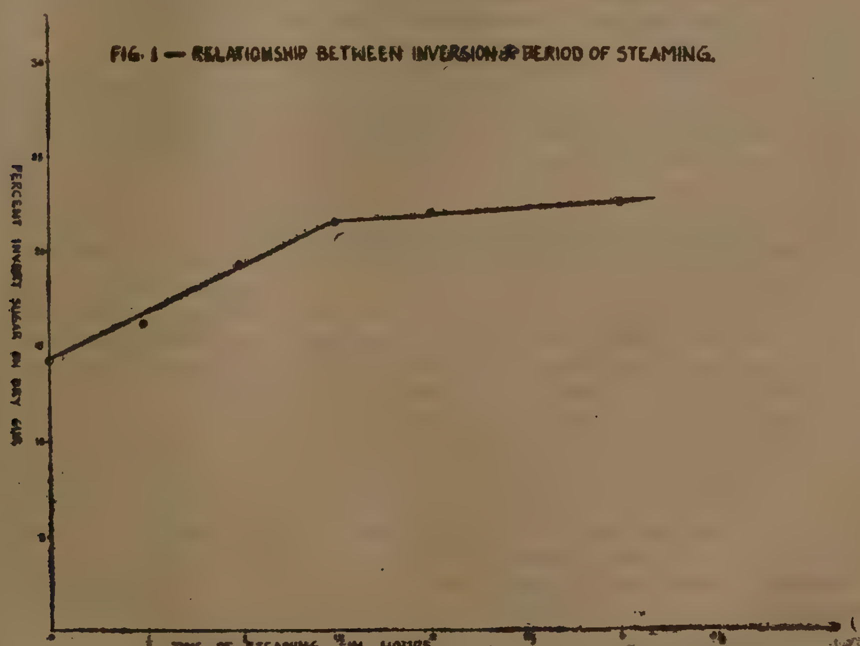

FIG. 1. Relationship between inversion and period of steaming

Systematic preparation and analysis of deodorized gur syrup

1000 gm. of gur of known analysis was made into a paste with 200 c.c. distilled water and was steam distilled for 1½ hours applying gentle suction. After steaming the brix of the syrup fell down to 60°. The steamed syrup was then treated with activated char and filtered. Sulphur dioxide was bubled through the filtrate till the colour changed from reddish yellow to straw yellow. The dilute syrup was finally concentrated to a brix of nearly 80. During concentration vigorous stirring helps in the removal of sulphur dioxide. The final syrup had a golden yellow colour with a pleasant odour unlike that of gur. The syrup in fact appeared better than golden syrup made from cane sugar. Table V contains constants for the gur and the syrup made from it.

TABLE V

Analysis of gur and of the deodorized syrup from it

(Results expressed on 100 gm. dry gur)

—	Syrup	Gur
Yield of syrup	84·2	..
Brix	81	..
Sucrose	59·13	76·60
Reducing sugars	30·2	10·98
Ash	2·16	2·81
pH	5·8	6·0

From the above data the quantity of gur recovered amounted to 68·25 per cent. Some of the gur is undoubtedly lost due to handling in the various operations and other extraneous impurities in the gur which are removed during filtration of the steam syrup also contribute to this loss.

Although the various samples of deodorized syrup from gur contained nearly 60 per cent sucrose, they still did not crystallize on standing. This was unusual because almost every sample of golden syrup prepared from sucrose crystallized with 60 per cent of sucrose in it. A search was, therefore, made for the cause in view of its great technical importance on analysis of a number of deodorized gur syrups which had shown signs of crystallization and stability in its fluidity it was found that sulphur dioxide was the chief agent affecting this phenomenon. From these investigations it may be said that sulphur dioxide serves three purposes (1) improves the colour of the syrup, (2) acts as a sterilizing agent, and (3) prevents crystallization even in the presence of large concentration of sucrose in the syrup.

Effect of sulphur dioxide on crystallization and stability of the syrup

The third point needed further investigation to ascertain the limits of sulphur dioxide concentration which would prevent crystallization in the syrup. Accordingly certain samples of syrup which remained fluid for a number of months and those which had crystallized on standing were examined for their sulphur dioxide content by a new method to be described elsewhere. A sample which did not crystallize for three months when freed of its sulphur dioxide by aeration for 2 hours and subsequent treatment with kaolin crystallized almost immediately. This clearly demonstrates that sulphur dioxide was mainly responsible for keeping this syrup in the fluid state.

Sulphur dioxide content of five representative samples recorded in Table VI gives an idea of the range of sulphur dioxide which may be useful in preventing crystallization. From the data presented a final concentration of about 0·7 per cent sulphur dioxide should be sufficient to prevent crystallization in a syrup containing sucrose to the extent of nearly 60 per cent. Concentration of sulphur dioxide will be considerably reduced when these syrups are consumed in dilute forms and in small quantities. Further in the aerated water industry where the deodorized gur syrups can be used with advantage in coloured drinks, whatever sulphur dioxide is introduced in the drink will be displaced by the charge of carbon dioxide. The question of the toxicity of sulphur dioxide in the syrup therefore does not arise.

TABLE VI

Effect of sulphur dioxide concentration on crystallization

	Sample which did not crystallize for 6 months	Sample which did not crystallize for 4 months	Sample which did not crystallize for 2 months	Sample which crystallized in 15 days	Sample which crystallized in 10 days
Per cent sulphur dioxide in syrup	2·21	1·39	0·78	0·57	0·27

Practical importance of the investigation. (1) Those who have a dislike for gur flavour can use gur in the form of deodorized syrup which will be cheaper than golden syrup, (2) during sugar shortage the industries concerned can make use of deodorized gur syrup in the manufacture of table syrup, *sharbats* and aerated waters, and (3) gur which might have deteriorated during storage can be profitably utilized.

Cost of production

(1) 10 md. gur (deteriorated) of light colour @ Re. 1 per md.	= Rs. 10	0	0
(2) Steam distillation and final concentration	= Rs. 5	0	0
(3) Kaolin @ 5 annas per lb.	= Rs. 2	8	0
(4) Sulphur dioxide	= Rs. 5	0	0
(5) Overhead charges	= Rs. 10	0	0
Syrup yield from 10 md. gur equivalent to 8 md. nearly	= Rs. 32	8	0

Cost per lb. of deodorized syrup = nearly 1 anna.

SUMMARY

A method of preparing deodorized syrup from Khandsari molasses and gur has been described. The process in brief consists of making a paste of gur in water of the consistency of a porridge and then steam distilling it for one hour and a half. By this time all the volatile bodies present as impurities in the molasses or gur are swept off. The steamed syrup is then filtered through a layer of kaolin which absorbs any other impurities thereby improving the colour and the colour of the syrup still further. The colour of the syrup is then finally improved by drawing a stream of sulphur dioxide through it. Final syrup is then obtained by concentration in basins or under reduced pressure.

The effect of sulphur dioxide on crystallization of syrups and the minimum quantity of this gas which prevents crystallization has been determined.

By this process gur which has deteriorated during storage can be profitably utilized by converting it into deodorized syrup.

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REVIEW

Some British Books on Agriculture, Nutrition, Forestry and Related Sciences 1939-1945—List compiled by H. M. Bedington.

(Imperial Agricultural Bureaux Joint Publication No. 11. Published July 1946. Price : 3*s*., Pp. 36)

THIS is a very useful publication embracing references on agriculture, nutrition, forestry and related biological and other sciences published during 1939 to 1945. A subject index has been provided so that one can easily find out the work he is interested in. It will be of great service to the workers concerned.—I.C.

PLANT QUARANTINE NOTIFICATIONS

Notification No. F.3-1/46-PP., dated the 17th August 1946, of the Government of India in the Department of Agriculture

IN exercise of the powers conferred by Sub-section (1) of section 3 of the Destructive Insects and Pests Act, 1914 (II of 1914), the Central Government is pleased to direct that the following further amendment shall be made in the order published with the notification of the Government of India in the late Department of Education, Health and Lands No. F.320/35-A., dated the 20th July 1936, namely :—

In paragraph 8B of the said Order, after the word " Burma " the words " or the Kalat State " shall be inserted.

Notification No. F.3-5/46-PP., dated the 16th September 1946, of the Government of India in the Department of Agriculture

In exercise of the powers conferred by Section 4C of the Destructive Insects and Pests Act, 1914 (II of 1914), the Central Government is pleased to direct that the following amendment shall be made in the notification of the Government of India in the Department of Agriculture, No. D.22-1/46-P., dated the 16th February 1946, namely :—

In the said notification, for the words " British India " the words " the Province of Madras " shall be substituted.

MGIPC—M—III-1-17—29-4-48—600.

The Editorial Committee, in its work of examining papers received for publication, is assisted in an honorary capacity by a large number of scientists working in various parts of India.

Editorial communications including books and periodicals for review should be addressed to the Secretary, Imperial Council of Agricultural Research, Publication Section, New Delhi.

Communications regarding subscription and advertisements should be addressed to the Manager of Publications, Civil Lines, Delhi.

Instructions to Authors

Articles intended for the *Indian Journal of Veterinary Science and Animal Husbandry* should be accompanied by short popular abstracts of about 330 words each.

In the case of Botanical and Zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

Reference to literature, arranged alphabetically according to author's names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets, when the author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state 'Original not seen'.

Sources of information should be specifically acknowledged.

As the *format* of the journals has been standardized, the size adopted being crown quarto (about $7\frac{1}{4}$ in.$\times 9\frac{5}{8}$ in. cut), no text figure, when printed, should exceed $4\frac{1}{2}$ in.$\times 5$ in. Figures for plates should be so planned as to fill a crown quarto plate, the maximum space available for figures being $5\frac{3}{4}$ in.$\times 8$ in. exclusive of that for letter press printing.

Copies of detailed instructions can be had from the Secretary, Imperial Council of Agricultural Research, New Delhi.